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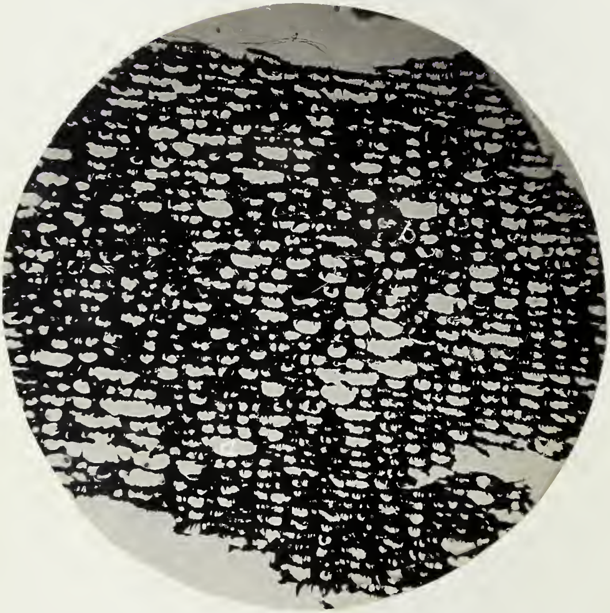
Frontispiece Plate I.



Section of wood from Edmonton Coal highly magnified.

THE ORIGIN, COMPOSITION AND OCCURRENCES OF COAL IN ALBERTA.

by

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University of Alberta
Edmonton
1916

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THE ORIGIN, COMPOSITION AND OCCURRENCE OF COAL IN ALBERTA.

Part I. THE ORIGIN OF COAL.

Chapter I.

INTRODUCTION, SUMMARY AND CONCLUSIONS.

Coal has a perennial interest for mankind. It is by far the most important mineral product known to the use of man. Upon it we are dependent for the necessaries and comforts of our life. It is the foundation of our civilization and indispensable to all nations.

Our knowledge of it is based upon the facts of many sciences. The botanist, the geologist and the chemist; the engineer, the sanitarian and the merchant have given years of labor and research to its economic application and utilization.

The word is derived from cole (Anglo Saxon Col) and was first applied to any substance that could be used as fuel. Its proper use however was as a suffix

like in charcoal which was long used as a fuel. The forests, which supplied the wood for charcoal, were the chief source of fuel in all countries until the middle of the nineteenth century. As wood became scarce charcoal fell into disuse and "pit coal" became more and more important and finally emerged without a rival. "Pit coal" or "earth coal" was the term originally applied to coal. Thus a purely popular term has fixed itself in science for which it is impossible to frame a strictly scientific definition.

In the past fifteen years a great deal of investigation and work has been done on coal throughout the world. The results however are scattered through many periodicals and scientific publications and so not easily accessible. The work done has considerably widened our knowledge of the subject. Some new experimental methods were devised that gave rise to new theoretical generalizations. The object of this paper is to collect the known facts and to set forth some of the results of their application to Alberta coals.

FIELD WORK AND ACKNOWLEDGMENTS.

Field work on coal has been carried on in Alberta by the writer since 1909. Most of the import-

tant coal mining centres have been visited and conditions economic and geological studied. New fields also, were examined and reported upon, for commercial interests during that time.

In the preparation of this thesis for the Degree of M. Sc. the writer wishes to acknowledge the generous assistance received from members of the University staff. Especial thanks are due Dr. J.A. Allan and Dr. D.G. Revell for helpful suggestions, kind criticisms and wide interest in the problems encountered; the writer's best thanks are also due Dr. A. L. Lehmann and Dr. F. J. Lewis for helpful discussion and criticisms of certain botanical and chemical problems. He also thanks the library staff for placing at his disposal all the literature they had referring to the subject of coal.

SUMMARY AND CONCLUSIONS.

The material out of which coal is made may have accumulated as drift, in peat bogs, or as sediments in open water.

The rate of accumulation may be taken as 1 foot in 300 years calculated from the peat bog theory. All kinds of plants and plant remains enter Edmonton coal but it consists essentially of mosses and conifers

and their remains.

Coal is but transformed peat. The transformation is started as a fermentation (bio-chemical) process in which bacteria was the important factor, and ends as a metamorphic (dynamochemical) process in which heat and pressure are the important factors. The above are the important elements in the genesis of coal and they combine in infinite complexity even in a single bed of coal.

The chemistry of the first or fermentation process is fairly clear and understood but the chemistry of the second is not so clear. In both it is evident the chemical changes took place along rational chemical principles, so from a knowledge of the materials to start with, certain deductions can be logically made i.e., the changes from unstable to stable compounds.

In the process of making peat the parts and products of the plants which were most resistant to the decomposing agents like bacteria and fungi, would survive longest. Among these are the resins, waxes, spore and pollen covers, cuticles, seed coats and bast of the many plants that contributed to the peat. Such a highly macerated product is represented in the

coal of today as the dull amorphous parts.

The softened but less metamorphosed stems, trunks, and branches are represented by layers or lenses of a dark, black or jetty, glossy character with high lustre.

Within the coal are present a darker and a lighter, more translucent resin. As seen in the sections under the microscope these resins comprise approximately one half the total mass.

Mineral charcoal forms an appreciable amount of the coal.

Chapter II.

METHODS OF ACCUMULATION.

To account for the accumulation of the vegetable matter that has formed the coal beds, three theories are advanced namely:-

(a) The drift method.
(b) The In Situ method.
(c) The sedimentary in open water.

By the "drift method" vegetation grew in one place, and was transported by means of water to another there laid down and later transformed into the coal seams we have today.

Captain Hall describes such an occurrence in one of the mouths of the Mississippi today. The width is 220 yards from bank to bank across which the raft extends. In length it covers a space of 20 miles of which only 10 is filled with timber. It is supposed to be 8 feet thick. It has been accumulating for more than 50 years and is made annually larger by

supplies from the river.

Fayol (1) has established the validity of the theory in the coal areas of Commentry in central France. De Lapparent (2) has applied the same hypothesis to other coal fields of the world.

The advocates of the theory cite in its support the constant dovetailing of the seams with shale and sandstone and the very irregular thickness of the coals themselves. The upright stems of trees, occasionally are found in the associated sandstones, that have been floated into place and subsequently covered by sand. Again well preserved ferns, leaves, branches, etc, that are in no way part of peat bogs, may abound in the beds underlying and more particularly in those overlying such coals.

By the growth "In Situ" method of accumulation the vegetable matter formed as a peat bog or possibly as the modern mangrove or cypress swamps. It may have developed partly on the low flat shores of estuaries and bays and partly in the salt water itself

(1) Bull. Soc. Ind. Min. Sept. 16, 1880.

(2) "L'Origin de la Hanill" Rev. quest. Scientif, July, 1892.

as marine shells are often found in the coal measures. These seams are uniform over wide areas and rest on clay or shale showing many rootlets. Coal measures so formed may be very thick and contain many coal seams. Such a succession of interbanded clay, shale, sandstone and coal indicate a prolonged period of frequent subsidence and rest. Each coal seam with its underclay represents a pause or rest in the movement of subsidence. See ~~plate~~ Fig. II.

The clays underlying the coal seams are the old soils upon which the vegetation grew. A close examination shows the roots and trunks to have a tendency to nodal development with the growth of roots from successively higher nodes.

Potonie (1) points to the size of the fragile plant segments and the state of preservation of the delicate fern laminae in the roof of coal beds as a proof of growth in place. Plants in transport are quickly twisted, rumpled, torn and disintegrated in the moving water of lake or river currents so they will seldom or never reach the bottom in a recognizable condition. Transported plant remains that may be

(1) Naturwiss-Wochenschr, Feb. 19, 1899, p 81.

observed today reveal nothing but comminuted, water worn, and somewhat macerated particles more or less graded in size like other sediments.

According to the sedimentary theory the vegetable matter forming coal has been laid down in water. In support of this theory Jeffrey (1) writes as follows:

"We are forced to conclude that the raw materials of coal were heaped up, not as the result of the growth of successive generations of plants on the prostrate and persistent bodies of those already fallen, but as the age-long gradual accumulation of vegetable matter in open water. In other words coal is not a compost heap but a sedimentary deposit. Striking as are our actual peat bogs in temperate climates, in reality they throw no light on the accumulation of vegetable matter in past ages, which has been preserved to us in the form of coal. The less conspicuous accumulations of vegetable matter in the bottoms of our lakes afford the real elucidation of the mode of formation of coal beds. As in our actual bodies of water, which accumulate vegetable deposits, the nature of the material laid down varies with the depth, tranquility of the water, and other conditions, so

(1) "The mode of origin of Coal", Jour. of Geol. Vol. 23, No. 3, 1915.

the nature of the coal derived from similar formations in past ages varies in composition. Where the spore material is more abundant the result is a cannel or an oil shale. Where it is still plentiful but not superabundant, we have coking and gas coal as a product. Where poverty is manifest in the spore content, lean or ordinary bituminous coals are formed. Devolatilization leads to the formation of anthracite."

In applying these theories to the coals of Alberta the evidence of the general sections and the megascopic character of the coal points most strongly to the growth "In Situ". Three classes of coal may be seen by the naked eye in almost any seam, namely charcoal, glance, and dull amorphous. These are composed respectively of charcoal, trunks of trees and humic acid jelly the result of decomposition. The great number of seams that have under-clays or the old soils upon which vegetation could grow is pretty strong evidence of growth "In Situ".

Chapter III.

RATE OF DEPOSITION AND KINDS OF ORGANISMS.

Of the three theories advanced to account for the formation of coal, only one, the "Peat Bog" theory, can be used to calculate the time involved in the accumulation of the deposit. Time cannot be calculated with either the drift or the water deposit theory.

Where a study has been made today of the peat bog it is found to grow at a certain rate. Assuming the most favorable conditions and the most rapid growth we have a figure that fairly represents the maximum rate of growth in the peat bog. Europe furnishes the best examples from which our knowledge of the rate of growth of these peat beds is had. For centuries certain peat beds have been dug for fuel upon which the rate of growth has been closely watched. At certain ancient architectural sites the growth of peat has been measured. The ruins at these sites are being gradually covered up by the growth of peat.

In these instances under the most favorable conditions peat has been known to form at as high a rate as one foot in five years. It is believed that a rate of one in ten years is a fair average maximum for normally favorable conditions.

The percentage of water in young peat may be as high as 85% to 95%. Under pressure this water is lost leaving the solid material first as peat and finally coal. Three hundred years is the time necessary for laying down one foot of coal.

To estimate the time required for laying down the coal of a given period in terms of the present conditions, we must know:

1. The maximum rate of peat formation.
2. The ratio of the peat volume to the resulting coal volume.
3. The maximum coal deposition.

Applying these principles to Alberta we have for the various coal formations, Edmonton, Belly River and Kootenai as follows:

EDMONTON FORMATION, comprises about 700 feet of strata of interbanded clay, shale, and sandstone with coal seams. The coal seams number probably 8 ranging in thickness, the workable ones, from 4 to

25 feet. These give a total maximum thickness of about 73 feet.

73 x 300 = 21900 years for laying down the coal.

BELLY RIVER FORMATION, is the second coal horizon and lies below the Edmonton and is separated from it by dark marine shales, which represent a period of depression below sea level. The quality of the coal in this formation is better than in theEdmonton and approaches true coal. A section of these measures is best seen at Lethbridge. The thickness of the coal bearing rocks is about 850 feet and contain 3 seams of coal with a total thickness of probably 12 feet.

12 x 300 = 3600 years for the deposition of the coal.

KOOTENAI FORMATION, is below the Belly River and separated from it by an immense thickness of dark marine shales which were laid down during a down warp of the earth's crust at the close of the Dakota period. This is the most important coal formation in Alberta and has consequently received the most notice at the hands of the engineer and geologist. A number of sections have been made extending from Peace River on the north to the Crows Nest on the

south. These show the coal to thin out rapidly to the northwest. This is well shown in the following sections:

The Crows Nest is the most southerly and as worked out by McEvoy (1) shows the measures to have a thickness of 4700 feet. There are 22 workable seams having a total thickness of 216 feet of coal.

216 x 300 = 64,800 years of coal deposition.

The Bow River section was found by Dowling to contain ten coal seams from 4 to 15 feet in thickness. The total amounts to 68 feet.

68 x 300 = 20,400 years.

The Red Deer section by Dowling (2) was found to contain in total coal 94 feet distributed in 15 seams between 4 and 11 feet in thickness.

94 x 300 = 28,200 years.

In the Brazeau River Section the Kootenai measures are found to be about 3600 feet thick and to contain 13 seams for total thickness of 89 feet, of coal.

89 x 300 = 26,700 years.

Athabasca River Section shows 3800 feet of

(1) Sum. Rep. of G.S.C. 1900, p 85.

(2) G.S.C. No. 1035, p 35.

Kootenai measures with 6 seams of coal of total thickness of about 46 feet.

46 x 300 = 13,800 years for the deposition of this coal.

Smoky River Section has Kootenai measures of about 2600 feet with total coal of 27 feet distributed in 5 workable seams.

27 x 300 = 8,100 years in which this amount of coal was laid down.

Peace River Section (1) by Galloway shows the Kootenai coal measures to be about 2000 feet thick and to contain 5 seams of the following thicknesses, viz; total coal, 1 ft. 4 in.; 3 ft. 3 in.; 3 ft. 11 in.; 3 ft. 4 in.; and 2 ft. 9 in. Grand total of coal 14 ft. 6 in.

14 x 300 = 4,200 years for the deposit of this coal.

These calculations show the interesting feature of how much of ancient geologic time was favorable to the formation of coal, of that period. Coal was laid down in the southern area for a period about 20 times as long as in the northern area at Peace River. This fact may be attributed to two causes which control

(1) B.C. Report of Min. Mines, 1912, p 118.

Plate II.

MAP OF ALBERTA.

the growth and distribution of plant life on the earth. These causes are climate and physical features of the times.

PHYSICAL FEATURES AND RATE OF DEPOSITION

The physical features in Alberta of the Cretaceous period may be outlined from the extent of the known sediments, of that age. The record of the geological changes during that period is found in the beds formed by the accumulation of sediments of sand and clay in what was then a vast interior sea on the North American continent. This sea divided the continent into an eastern and a western one. The sea extended from the gulf of Mexico northwesterly to the Yukon. In Alberta it covered what is now the plains region as far west as the Rocky Mountains.

Among the records preserved in the sediments of sand and clay laid down during those times are the coal seams of the Kootenai measures at the base of the Cretaceous system. These form by far the most important page in the history of these times. They indicate a region of coastal swamps, tidal flats, a succession of lakes and alluvial river plains, lacustrine conditions on a wide scale that

reached from Mexico to the Yukon, and extended to some distance east of the region now occupied by the Rocky Mountains.

At the close of the Dakota period a wide spread depression allowed the sea to spread over these lacustrine areas for a time. This record is found in the deposit of marine shales of Benton, Niobrara, and Claggett ages. Eventually lacustrine conditions were again restored and its history is found in the coal beds of Belly River age. These also extend from Mexico to Yukon a distance of more than 2000 miles and 4 to 500 miles wide. Finally the Cretaceous ends as it began by a mountain building uplift.

The Cretaceous was inaugurated by the uplift of the Sierra and Cascade Ranges and it was brought to a close by the Rocky Mountain uplift. As a result of this the whole plains region was arched, the Cretaceous sea abolished and the continents became one. Great changes in physical conditions resulted and are recorded in the Edmonton coal beds. The sea was not entirely abolished but continued on in remnants as lakes to the close of the Cretaceous. These lakes passed through brackish water stages to fresh water in the Tertiary period.

In Tertiary times we have the records of the sediments laid down under fresh water conditions. Among these are the coal beds of the Paskapoo. These are the remains of a luxuriant vegetation that flourished in the swamps and lagoons that formed around the shores of the lakes of those times.

This succession of events is well illustrated in the series of formations in the following table in descending order as given in Dowling's Coalfields of Manitoba, Saskatchewan and Alberta, page 20.

We thus see that the physical features of Alberta in the coal bearing times profoundly influence the rate of deposition of plant remains. They might cause a cessation entirely as when an area is submerged in the sea or raised above to a high altitude giving rise to rapid erosion. Or again they may offer conditions for a maximum growth as in swamps and lagoons along the sea coast and lake shores when the climate is suitable.

CLIMATE AND RATE OF DEPOSITION: The climate of a continent controls very largely the distribution of life, both plant and animal, upon it. It also largely determines the kind and character of the soil. On a proper soil life abounds if the rainfall

	GROUPS	ALBERTA	KINDS OF ROCK	CHAR.OF FOSSIL	ECON.VAL.
TERTIARY		Miocene	Conglomerate & Sandy Clay	Land & Fresh Water	
		Paskapoo			
CRETACEOUS	Montana	Edmonton	Sandstones & Sandy Clay	Fresh Water	Coal
		Bearpaw	Sandstone & Clay	Land Plants Brackish Water Marine &	
		Belly River	Shales & Sandst.	Brackish Water	Coal
		Claggett	Shales	Marine	
		Eagle	Sandstone	Marine	
	Colorado	Niobrara	Calcareous Shales	Marine	
		Cardium			
		Benton	Shales	Marine	
	Dakota	Dakota	Sandstones	Fresh Water	Some Coal
	Kootenai	Kootenai	Sandstones & Shales	Land Plants	Coal

is sufficient and the temperature favorable.

A uniform climate is one whose range of temperature is small, the rainfall equally distributed and the winds constant in direction and strength.

In passing from Jura-Trias to Cretaceous times notable floral changes occurred, viz:

1. Many older types Equiseta (horestails) disappear.
2. Angiosperms first appear.
3. Gymnosperms (naked seeds) show advanced differentiation.

The floral changes consist of, briefly, the following: In the lower orders of plants, in the Bryophytes, and most Pteridophytes (ferns) there is an alternation of generations in the reproduction of the species. That is the spore grows into an intermediate sexual state called the prothallium which in turn grows the sexual organs, and these in turn after fertilization grow into the natural species of the plant. In ~~Pteridophytes~~ Lycopodiales the prothallium is of little importance hence there is a noticeable increase in the differentiation of the spore before its separation from the parent plant. The spores have become (1), small ones, microspores which are

strictly male as to their functions, and (2) large ones, macrospores, which are as strictly female.

In the ~~Phanerogamia~~ Gymnosperms ~~and Angiosperms~~ the changes begun in the Pteridophytes proceeds a step further. ~~The differentiation into male and female organs is carried back far beyond the formation of the microspore~~ (~~pollen grains~~) ~~and macrospores~~ (~~embryo sacs~~). The macrospore does not sever its connection with the parent plant, but continues to be nourished by it until after the embryo is formed. In consequence the prothallium (endosperm) is but feebly developed. ~~The prothallium is essentially a nourishing structure made necessary by the fact that the reproductive bodies separate from the parent before they are ready for fertilization~~. Thus in phanerogams where parental care extends until after the formation of the embryo there is generally only the smallest rudiment of a prothallium. In ~~them~~ this group are produced two kinds of reproductive cells, viz, pollen grains and embryo sacs, the homologues respectively of microspores and macrospores. The portions of the plant body which produce these cells together with the modified parts enclosing them is known as the flower.

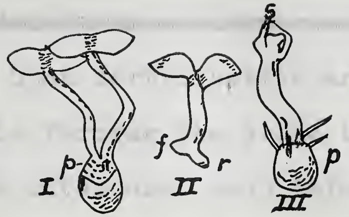

FIG. I. I. Two young plants of Selaginella Martensii growing from the same spore; at the top of the spore may be seen the projecting prothallium, p. This illustrates the possible origin of the first cotyledons.

II. A young plant drawn out of the spore, showing the foot, f, on the left below, and the young root, r, on the right.

III. A young plant whose first leaves (cotyledons) have been removed, leaving only the stipules, p; between the latter is seen the dichotomously dividing punctum vegetationis, s, the prothallium isolated from the spore.

I. x 8; II. x 3½; III. x 30. After Hofmeister.

~~Within the flower the ovule in its development becomes surrounded by one or two coats, which grow from its base~~. Upon fertilization an embryo forms and while this is forming the ovule becomes greatly enlarged and its outer coat much thickened and hardened. It is now called the seed and soon separates from the parent plant.

These are the changes in the flora which the Cretaceous ushered in. They suggest pronounced changes in the climate of the times.

CLIMATIC CHANGES may be produced by one or all of three causes, viz:

1. Atmospheric,
2. Astronomic,
3. Topographic.

The topographic is the only one we need notice. The mountain building Sierra and Cascade uplifts at the close of the Jura-Trias brought about a new climate, still mild but more variable than any the plant life had yet experienced. We have seen how this climate produced great changes in plant life, notably in the care the parent plant bestows upon its offspring. The seed they produced has considerable plant food stored in it, so they are better

suited to meet varied conditions at the period of germination. The mountains that had been pushed up from below the sea offered barriers to the currents of the air. Regions of high altitude not only extracted the moisture from the air but also gave a greater range in temperature. Rainfall would thus be less uniformally distributed and to the winds a barrier was offered that changed their direction and strength.

THE CRETACEOUS CLIMATE has been characterized as follows by Mr. D. White (1): "A mild climate early characterized Cretaceous times in Alberta as shown by the presence ofmany ferns and cycads, known tropical plants in the Kootenai coals as far north as Greenland and Alaska. The relative indistinctness of the annular rings in the wood in these coals also points to this fact. Dicotyledons for the first time began their participation in the formation of coal. The Kootenai coal measures show the first remains of Angiosperms. This genera developed with amazing rapidity and early dominated the plants of the landscape. Many genera of ferns that are still living appeared as Aspidium, and Asplenium. Among the

(1) The Origin of Coal, Bull. No. 38, U.S.G.S.

Gymnosperms many genera also first appeared and are still living such as Sequoi, Torreya, Glyptrostobus, and Zamia."

"The Flora of the Dakota sandstone, which caps the Kootenai measures, is largely dicotyledons. Coal is sparingly found in these sandstones. Hardwood trees such as figs, and cinnamon of subtropical type are included in its composition. These signify a mild humid climate as mild at least as that of the Carolina coast of the present day."

"The Colorado group times are also characterized by mild humid climate as indicated by the fern genera, a tropical and subtropical plant, Gleichenia."

"The Montana group of upper Cretaceous is also coal bearing. Among the plants are abundant palms of several genera; ferns like Gleichenia and Aneimia; banana trees; hardwood genera such as fig, the Euclyptus and the bread fruit. Knowlton regards this flora as conclusively showing a climate milder than southern Atlantic coast."

"The (Laramie) Edmonton formation or upper-most Cretaceous is coal bearing. The plants associated with the coal of this age includes figs, breadfruit, and palms, pointing to a temperature as mild as the

Gulf of Mexico of today."

"The Tertiary Coal Measures show climatic differentiation from which no complete recovery was gained. The plant associations and wood structure show the existence of climates as mild as that in the southern states at the present time. These extended to the Yukon and Alaska."

The type plants from which the above conclusions were drawn are to be found in Alberta, without exception, almost. The types are the same for the respective formations as given by Dowling and Malloch (1) and (2). The climate was uniform, mild and humid for each of the coal periods(3)(4). This was necessary for a quick growth and luxuriant plant life. Without a favorable climate the processes of decay equal those of growth and so no vegetable matter accumulates as in a peat bed.

KINDS OF ORGANISMS: Everybody who has looked at coal has probably observed distinct woody layers in it and often charcoal. In these coals the softer tissues have become obliterated through the

(1). Coal Fields of Man.Sask.Alta. G.S.C. p 30.

(2). Bighorn Coal Basin, G.S.C. p 48.

(3). White, Bureau of Mines, Bull.38. p 67.

(4). Doubt exists with some as to climatic conditions they inclining to the belief it was as cold and variable as that of to day. Sufficient is not known probably yet to draw final conclusions. Peats are not formed in tropics or subtropics to day as generally as in colder climates.

macerative process no doubt going to make up the fundamental matter of jelly in which the more resistant particles are suspended. To this fact is largely due the general belief that lignites and other coals have passed through an early stage homologous with peat formation.

Kinds of Plants in Peat Formation may be considered under three heads, viz: (1) Aquatic Plants; (2) Seed Plants; (3) Aquatic Seed Plants.

AQUATIC PLANTS are among the lowest forms of plant life and may be first noticed. These are the Algae or "pond scum" of bright green color that live anywhere in water. They are quite simple plants, some unicellular, others aggregated into surfaces. In the next great group of plants higher than the Algae, none ofimportance is exclusively aquatic until the mosses and liverworts (Bryophytes) and the ferns (Pteridophytes) the so-called Vascular Cryptogams are reached.

The mosses and liverworts are small in size, simple in structure, though of a much greater degree of complexity than the Algae. In all the mosses and some of the liverworts there is a stem and leaves but generally no true roots, the place being taken

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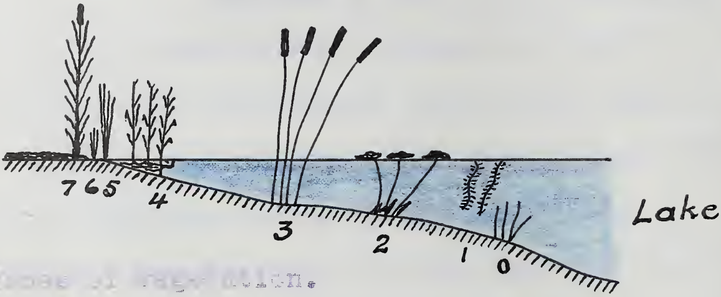


Zones of Vegetation.

0. Charas. 1. Floating bladderwort.

2. Yellow pond lily.

3. Lake bulrushes. 4. Sartwell's sedge.

5. Bottle sedge 6. Spike rush.

7. Cat-tails.

(After Davis).

Fig. II.

by rhizoids. The mosses will flourish both below and slightly above water level. A few ferns are aquatic but more of them are found among the seed plants.

SEED PLANTS have a complicated organism, made up of various kinds of tissues, some of which possess great strength, that enables them to grow to large size. They contribute largely to the accumulations of vegetable matter. Being land plants only a small number are truly aquatic. Most of these grow by roots from the bottom of the lakes and rarely in water of greater depth than 15 to 18 feet. Sufficient light and heat will not penetrate deeper to start life or maintain it once started.

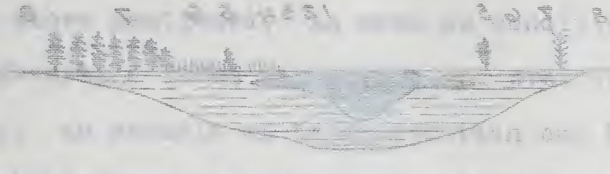
ZONES OF VEGETATION are found upon the shores of ponds and lakes. The zones are more or less concentric around the deep water. In the Northern United States where studied, each zone is dominated by certain group of plants. From the shore outward to deep water they are: 1. Amphibious sedges, carex, etc, especially the turf forming, carex filiformis.

2. Lake bulrushes, Scirpus.

3. Pond lilies, Castalia and Nymphaea.
4. Pond weeds, Potamogeton.

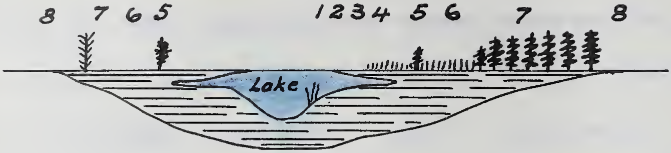
[illegible] give [illegible] the water [illegible]
and provide continued root growth. The plants flourish

[illegible] the edges of [illegible], is spread over the
bottom of the lake and the water becomes shallower.
[illegible] plants spread [illegible] and [illegible] in the
water [illegible]



[illegible] [illegible]
[illegible] part of [illegible] a [illegible] of the [illegible]
Typha latifolia, [illegible]
[illegible]
[illegible] on the [illegible] of the [illegible]
[illegible]
[illegible] with [illegible] and [illegible]. The
[illegible], [illegible] [illegible]
[illegible] [illegible]

[illegible] of [illegible] is [illegible] growth.
[illegible]. The plant is [illegible] and [illegible]
[illegible] in [illegible] [illegible]. [illegible]
[illegible], [illegible] of the [illegible] of the
[illegible]. The growth is rapid, [illegible] the
bottom of the stream but [illegible] [illegible]
[illegible] [illegible] water [illegible]. [illegible]



Vegetation filling a Lake.

1. Chara, and floating aquatics.

2. Pond weeds. 3. Water lilies.

. Floating sedges, moss.

5. Advance plants of conifers and shrubs.

6. Shrubs and Sphagnum zone.

7. Zone of tamarack and spruce.

8. Marginal zone.

(After Davis).

Fig. III.

5. Algae live in open water of any depth and certain rootless seed plants. See plate opposite.

As the mass of debris is spread over the bottom of the lake and the water becomes shallower these plants spread into the new territory in the order above mentioned. As soon as conditions become favorable herbs and shrubs and even trees appear. An example of this condition can be admirably studied west of Edson where a cut on the Grand Trunk Pacific drains a large lake once known as Duck Lake. From the water's edge the moss spreads inland for long distances on the shores of the lake. Near the water's edge ice shoves had raised the vegetable mould 6 to 8 feet above the surrounding and upon this herbs, shrubs, and trees grew. Some poplar, pine and spruce were 6 to 8 inches through and willow brush. See the plate opposite.

SPHAGNUM or PEAT MOSS is a purely aquatic plant. The plant is large and varies in color from grayish-green to whitish and pinkish. It is widely distributed, grows at the top and dies at the bottom. Its growth is rapid, quickly raising the surface of the swamp but the height is limited to which it can raise water from below. This seldom

exceeds a few feet except in very moist climates. If the water level raises with the upgrowth of the peat as in poorly drained areas, the moss debris may become many feet thick. Examples of these may be seen in the heavy railway cuts along the Grand Trunk Pacific west of the Pembina River. This is a country of almost unbroken muskeg for 60 miles east and west and probably as great distances north and south. Their maximum depth is unknown. Many parts are the so-called floating muskeg, upon which are a few scattering scrub tamarack.

CONIFEROUS TREES follow the shrub and sphagnum. Among the common are the tamarack, Larix laricina, the only conifer found on floating muskeg, the black or swamp spruce, Picea mariana; the Arbor vitae (white cedar) Thuga occidentalis; the pines especially the scrub pines, Pinus banksiana; Pinus rigida, and less often the Pinus strobus. First they appear as scattered individuals but eventually cover the entire area.

DECIDUOUS TREES end the cycle following the conifers. As the dominant species they mark the stage where the soil is kept stable by the accumulations from above, keeping pace with the decay below.

At any time should the water level r ise, the trees will be destroyed and the peat forming begin again and repeats the above cycle. Such is the theory of the sequence of plants in water filled basins or lakes. Such structure has seldom been reported in coal deposits and it has, therefore, been concluded that workable coal beds seldom originate in water filled basins. On the other hand the remains of woody plants can be recognized throughout the entire thickness of many coal beds. This would indicate that they had been formed and built up from a soil surface originally little above water level or so little below it that woody plants could flourish with their roots in the wet soil. Modern swamp forests in Alberta presents identical conditions of growth. Where the peat formation happens to be on a subsiding coastal area and the accumulation of vegetable matter equals the subsidence, the same kinds of plants could theoretically continue to form peat indefinitely. Modifying causes enter to alter such conditions into the salt marsh. Under the preservative influence of the salt water the vegetable matter is stored in the strata of the

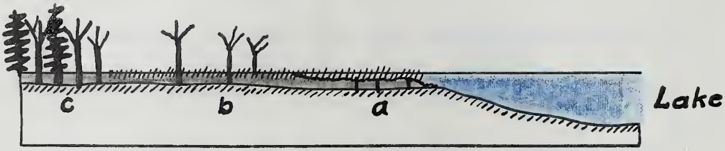


Diagram showing the progressive stages of invasion of a forest by a swamp.

a. Stumps.

b. Dead trees.

c. Forest invaded by swamp growth.

(After Shaler).

Fig. IV.

earth to be later transformed into coal by the agencies of pressure and heat.

Of our modern trees like maple, beech, poplar, hickory, oak, walnut, sycamore, willow, etc, nearly all were present in early Cretaceous times.

Chapter IV.

DECOMPOSITION.

In the preceding chapter mention was made of some of the kinds of organisms that form our peat beds. Before discussing the decomposition of these organisms it may be well to briefly review their nature and constitution. In this way we can gain an idea of the nature of the materials entering the processes of decomposition.

PROTOPLASM is the name given to the living portion, the active, vital thing of plants; that which is sensitive, which moves, appropriates food, and increases in size. Its exact chemical composition is not known, but it is known to be a watery albuminous substance, combined with a small quantity of ash.

The Plant-Cell: In some cases plant protoplasm has no definite or constant form. Usually however it appears in more or less rounded or cubical masses

with or without a cell-wall. In this condition it constitutes the plant-cell.

CELLULOSE: In all but the lowest plants the protoplasm of every cell surrounds itself sooner or later with a covering or wall of cellulose. This is a secretion from the protoplasm and as such does not exist in the protoplasm but is formed on the surface when the wall is made. Cellulose is related chemically to starch and sugar. Its composition is $C_{12}H_{20}O_{10}$ or $C_6H_{10}O_5$ according to other authorities. It forms as it were the ground work of all vegetable tissues. It is tough and elastic.

PRODUCTS OF THE PLANT CELL: The plant cell has a number of important products, viz:

1. Chlorophyll
2. Starch
3. Aleurone and Crystalloids
4. Crystals
5. Cell-sap
6. Oils, resins, gums, acids and alkaloids.

CHLOROPHYLL is a peculiar chemical compound to which is due the green color of certain portions of the plants and the plant-cells. Its exact chemical composition is not known but it probably

contains carbon, hydrogen, nitrogen, oxygen and iron.

STARCH next to chlorophyll is one of the most important products of the plant-cell. It is closely related to sugar and cellulose and is represented by the emperical formula $C_6H_{10}O_5$. It may be said to be a product of protoplasm just the same as cellulose.

ALEURONE and CRYSTALLOIDS are two of the most important bodies of albuminous matter given rise to by protoplasm in the ripening of seeds and tubers. The crystalloids though bounded by plane surfaces are not true crystals. In form they may be cubical, tetrahedral, octohedral, etc. The nature of aleurone and crystalloids is not understood.

CRYSTALS appear to be more numerous in the higher groups of plants and least so in the lower Bryophytes (mosses) and Pteridophytes (ferns). Calcium oxalate is the most important, then calcium carbonate and then calcium phosphate, Cal. sulphate and silica.

The CELL SAP saturates all parts of the living cell. Among the more important substances dissolved in the cell sap are sugar and inulin. Of the former

there are many kinds including cane sugar $C_{12}H_{22}O_{11}$ and glucose or fruit sugar $C_6H_{12}O_6$ which differ in sweetness and other properties. Inulin $C_{12}H_{20}O_{10}$ is a substance related to sugar and starch.

OILS, RESINS, GUMS, ACIDS, and ALKALOIDS. The fixed oils as castor, olive, linseed, and palm oil are secreted in many plant cells. In some instances the tissues contain 35% to 40% oil. The essential oils, the resin and gums are mainly the products of special cells in the plant. Resins are much like the essential oils in composition and generally are associated with and dissolved in them. Gums are sometimes related to sugar and starch as gum arabic, and others to the resins. Pectin or vegetable jelly $C_{32}H_{48}O_{32}$ is also related to the foregoing. In addition to oxalic acid $C_2H_2O_4$ which is generally found combined with calcium there are other vegetable acids some of which are even more common, viz, malic $C_4H_6O_5$, tartaric $C_4H_6O_6$, citric $C_6H_8O_7$, and tannic acid $C_{27}H_{22}O_{17}$.

PLANT CELL AGGREGATIONS: The plant cells in the vegetable kingdom are found principally under the following conditions of aggregation, viz:

1. Single Cells
2. Families
3. Fusions
4. TISSUES

Of these aggregations we need only notice the TISSUES of which the following are some of the principal varieties:

PARENCHYMA tissue is the most abundant tissue in the vegetable kingdom. It is the most important and most variable. It makes up the whole of the substance of many of the lower plants. In the higher plants the assimilative (green) and reproductive as well as vegetative (growing) parts are composed of parenchyma.

SCLERENCHYMA tissue forms the hard parts of many plants. It occurs in [illegible], pteridophytes, and phanerogams.

Other tissues like collenchyma, laticiferous, sieve, and tracheary need only be mentioned.

TISSUE SYSTEMS: As cells aggregate to form tissue so tissues differentiate to form into systems. One system is modified to form the bounding tissue, another the supporting and another the conducting system of the plant.

These systems fall into three groups, viz:

1. The Fundamental System.

2. Epidermal System.

3. Fibrovascular System.

THE FUNDAMENTAL TISSUE SYSTEM: This includes the mass of unmodified or slightly modified tissues found in greater or less abundance in all plants except the lowest.

THE EPIDERMAL SYSTEM is composed mainly of the boundary cells and their appendages (hairs, scales, etc). It is the simplest tissue system and the earliest to make its appearance in passing from lower to higher forms of plant life. In Bryophytes (mosses) there is in general a poor epidermal development. In Pteridophytes (ferns) the system is possibly as fully developed as in phanerogams. The outer layer of the epidermis is called the cuticle and frequently upon the surface is developed a waxy or resinous matter constituting what is called the bloom of some leaves and fruits.

THE FIBROVASCULAR SYSTEM comprises those aggregations of tissue which make up the string-like masses found in leaves and herbaceous plants. It forms the wood part of trees, etc. Wood and bast are the two varieties of the fibrous tissue.

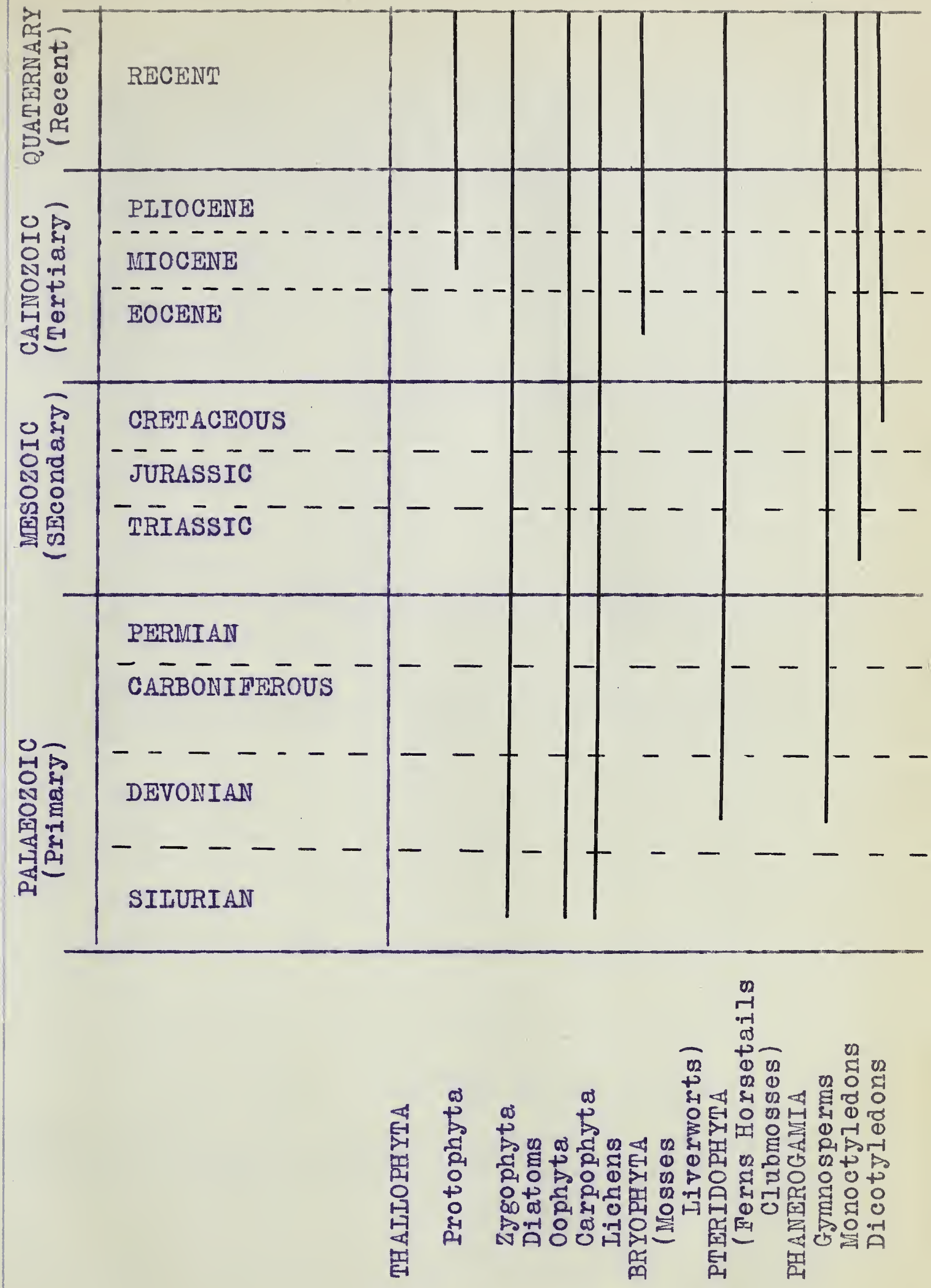
No doubt certain chemical characters are im-

parted to the coal by the kinds of debris, the tissues and certain of the above plant contents and the products of their natural distillation. A better understanding of the connection between the characters of the original ingredient materials and the chemical qualities of the coal may be had by a look at the distribution of plants in time. In doing so an idea of what plants and their products are, may be looked for in any coal bed.

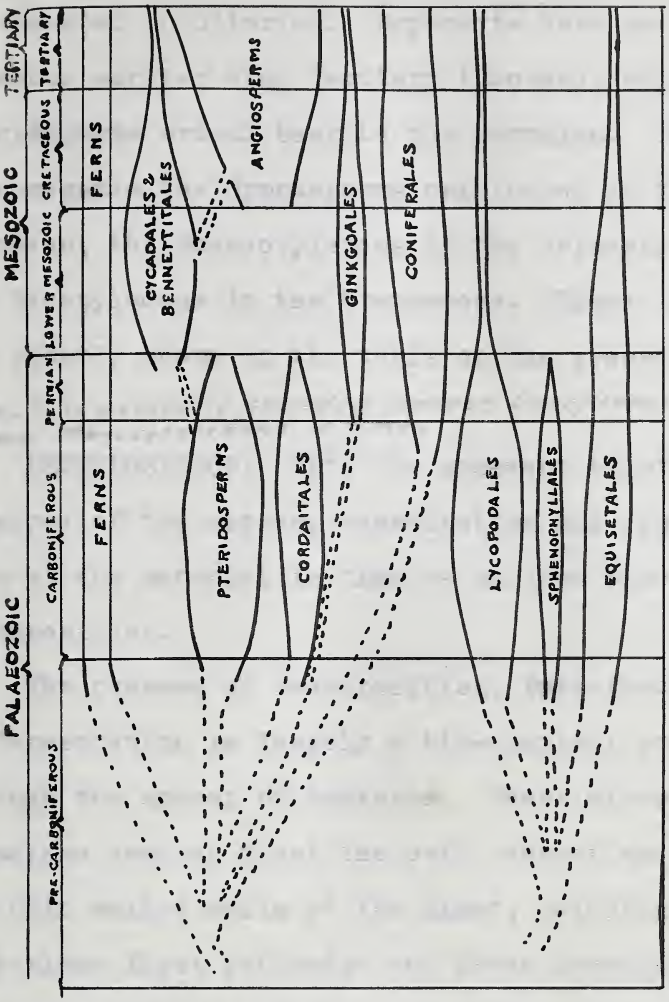
From their softness of texture and easy perishability we need not expect to find many remains of simple organisms like ~~Protophyta~~, Thallophyta ~~Zygophyta~~, and Bryophyta. Doubtless we must in the same way account for the fact that most of the species of fossil Phanerogams are trees and shrubs; the softer tissues of the herbaceous species yielding few fossils. These facts are clearly shown by the tables on the next page.

THE DISTRIBUTION OF PLANTS IN TIME. Schimper (1) early brought together what was known as to Fossil Botany. In his work he shows the Distribution of Plants in Time. He finds no fossil Protophyta earlier than Tertiary (Miocene). Zygophyta, Oophyta and Carpophyta with scarcely any doubt were well

(1) "Traite' de Pale'ontologie Vegetale," par Schimper 1874. Paris.
His classification is now out of date being made 1874.
Stopes Table now supercedes it.



See Table on next page



STOPES TABLE TO SUPERCEDE SCHIMPERS

Diagram showing the relative distribution of the main groups of plants through the geological eras.

represented in Silurian. Bryophyta have not been detected earlier than Tertiary (Eocene), while Pteridophyta extend back to the Devonian. Of the Phanerogamia, the Gymnosperms originated in the Devonian, the Monocotyledons in the Triassic, and the Dicotyledons in the Cretaceous. These facts are clearly shown by the table on the preceding page. It is generally conceded however Dicotyledons appeared before Monocotyledons in time.

DECOMPOSITION: With the somewhat brief review as above of the nature, constitution and distribution of the material in time we may now pass to its Decomposition.

The process of Decomposition, Putrefaction or Fermentation is largely a bio-chemical process, through the agency of bacteria. These micro-organisms destroy first the cell content and then the thin walled cells of the plant, coloring the protoplasm first yellowish and later brownish. If the process is arrested at this stage the mass remains brown and is of a flocculent consistency. If the supply of oxygen is ample, the process goes on until the most indestructible parts of the plant such as the cuticle, seeds, spores, etc remain in

a dark jelly-like mass, composed largely of humic acid. When the bacterial decomposition is complete all vegetable tissues are destroyed and if there is free access of air and oxygen even the jelly is broken up and converted into humus.

The fermentation stops it would appear from the death of the bacteria themselves, owing to want of a supply of oxygen. This supply may be stopped by want of air or by the by-products formed from bacterial activities such as humic, ulmic and tannic acids, or the antiseptic toxins in which they can no longer live. No doubt the completeness of the fermentation affects the composition of the coal.

CHEMISTRY OF DECOMPOSITION of plant material. It was pointed out earlier in this chapter that we do not know the chemical composition of some of the materials composing plants, like protoplasm, for instance. Our knowledge of the products of decomposition of these materials is equally incomplete. It can, however, be confidently asserted that whatever changes took place in the decomposition of plant material lay in rational chemical principles. We would look for the decomposition

to proceed along the line of change from unstable to stable compounds. Soluble compounds would be dissolved and washed away with the water. The gaseous products would conform to the laws that govern them.

The chief characteristic of the process is the accumulation of carbon at the expense of oxygen and hydrogen. This is illustrated in the following table. (1)

	C.	H.	O.	N.
Oak wood	50.20	6.08	43.74	
" decayed	53.50	5.16	41.34	
Humus of " oak wood	56.0	4.9	39.1	
Peat "Dartmoor"	59.73	5.91	31.82	2.54
Lignite coal	67.85	5.76	23.39	0.58
Bituminous coal	78.46	8.11	13.73	
Anthracite "	91.87	3.33	3.01	0.84

The chemistry may be considered under the following heads:

1. Bacteria and Oxygen.

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(1) Cellulose, Cross and Bevan, 1910.

2. Bacteria and Hydrogen.
3. Purely Chemical Reactions.
4. Hydrocarbons.
5. Bituminous substances.

1. BACTERIA and OXYGEN. Compounds rich in oxygen are more readily decomposed than those with little or no oxygen. The bacteria like other living organisms require oxygen for its life functions. If free oxygen is not available they attack the medium in which they are living to secure it, hence fermentation. In this hunt for oxygen the chemical compounds composing plant tissues are broken up into other compounds which may differ widely from the original. The following examples illustrate this:

Plant tissue like cellulose, hydro-cellulose, pectin and starch are broken up by bacteria and give -

a. Compounds like methane (CH_4), Carbon dioxide and hydrogen.

b. Compounds like acetic acid, butyric and valeric acids, aldehyde, ethyl, butyl, and propyl alcohol, which may be further reduced to paraffins

which contain no oxygen.

Some of these compounds are dissolved in the water and washed away. Others escape as gases, while others remain behind as solids or combine with others while in the nascent state. Compounds rich in oxygen are thus eliminated while those with little or no oxygen are left behind. The original substances as vegetable matter may contain between 42% and 54% oxygen whereas the residue may contain only two atoms of oxygen.

2. BACTERIA AND HYDROGEN: Hydrogen is given off continually as the result of bacterial activity. Being in the nascent state it would combine with other elements, and as it has a strong affinity for oxygen it would become a strong reducing agent in eliminating oxygen from the material.

3. PURELY CHEMICAL REACTIONS; are those brought about without the aid of bacteria. Both hydrogen and oxygen are eliminated by the process of dehydration. The process is readily illustrated in the laboratory by pouring strong sulphuric acid upon pine shavings or a lump of white sugar. The acid withdraws the water from the material so actively as to char it instantly. Such reaction probably

accounts for the large amount of charcoal to be found in coal. Further the fatty acids are reduced to paraffins, and glycerine, a constituent of all oils and fats, is reduced to alcohol and propane.

4. HYDROCARBONS are present in coal in large quantities. As they are not present in the life functions of the plant they must be formed during the process of coal formation. The higher solid hydrocarbons like paraffin may be present in coal originating from reactions above described. Cohen and Finn (1) recently found them oozing from the roof of a Yorkshire coal seam. The lower members of the paraffin series are present and constantly evolved from all mines. Methane is present in greater or less quantity in all mines gases.

5. BITUMINOUS SUBSTANCES; are composed of resins, waxes, oils, and fats. These in the life functions of the plants were stored food (as oils and fats), protective (as waxes), and excreta (as resin). In keeping with their life functions in the plant they are very stable compounds. They are present in large amounts in coal. They are rich

(1) Origin of Coal, D. White, Bull 38, U.S.G.S.

in carbon and hydrogen and low in oxygen as the following table illustrates: (1)

	C.	H.	O.
	%	%	%
Resins, resinoles and resinolic acids	76.8to 83.63	9.7 - 12.9	0 - 11.11
Waxes	80.32- 81.6	13.07- 14.1	4.5- 6.61
Fats, oils & fatty acids	74 to 78	10.26- 13.36	9.43- 15

Thus we see that through the ordinary processes of reduction, elimination, and dehydration, there is a concentration of stable compounds and an elimination of the unstable ones. The free carbon, resin, wax, fat and oil are more and more concentrated from the plant material to form what we know as coal. It is possible to make theoretically a mechanical mixture of the carbon, resin, wax, etc, that would agree with the chemical composition of almost all the classes of coals. There is but little doubt that the bituminization of coal results from the resin, waxes, etc, in it. The degree of bituminization depends upon the amount of these materials the coal contains. In the same manner shale becomes bituminous.

(1) Origin of Coal, D.White, Bull.38,U.S.G.S.

Chapter V.

METAMORPHISM.

The more important of the forces by which the metamorphism of coal is brought about are Time, Heat, Pressure, Crustal Movements and Perosity of the rocks.

TIME: According to many persons coal may be graded according to the Geological age, Tertiary, Cretaceous, or Carboniferous, ~~it belongs to~~. This is based on the impression that time is one of the important elements in the transformation of vegetable matter into coal. It is doubtful however if the character of the coals found are general enough to warrant the belief.

HEAT: Heat is one of the great transforming forces and is competent to produce all the grades of coal known in Alberta. In volcanic regions in other countries where the molten lavas have come in contact with coal beds, lignites have been

changed to bituminous, bituminous to anthracite and anthracite to natural coke. In regions like Eastern Alberta far removed from centres of volcanic activity, it is the internal heat of the earth that is the active cause of the change in coal. The process is a destructive distillation of the vegetable matter somewhat similar to the distillation of the same material in a retort. In a retort however the products can escape as fast as formed. In nature the beds of coal or peat alternate with layers of clay, shale, sandstone, etc, which prevents the free escape of the products of distillation. The extent of change depends on the rate with which the products can escape. If they escape as fast as they are formed the change depends upon the amount of heat applied as in a retort. If however, the strata above and below the coal is impervious, gases cannot form and consequently there will be little change despite the fact that considerable heat and pressure have been applied.

PRESSURE manifests itself as heat and can scarcely be separated from it. From the above discussion it will be seen that the whole process is controlled by the porosity of the enclosing rocks.

POROSITY OF THE ROCKS: This in general depends on the character of the elements forming the original rock. To this may be added joints, cleavage, planes and crustal movements and time. The older the rock the longer it has been subjected to crustal movements, shears and strains which tend to produce joints and cleavage planes. These afford the avenues of escape for the gases of distillation and thus facilitate the transformation of coal.

NATURE AND ENERGY OF CRUSTAL MOVEMENT.

If we examine in the field, coal measure deposits which have undergone folding or contortion, we shall gain an idea of the enormous pressures and lateral thrusts to which they must have been subjected. It is no doubt impossible to separate the effects of each of the forces, heat, pressure and porosity, but the effect is easily discernible. The effect differs with the type of rock in question. Sandstones and shales associated with coal are often little altered structurally, though they bear many external evidences of the pressures which they have undergone, in slickensides and zones of fracture. On the other hand the mother of coal was a comparatively soft, unstable accumulation

and we can readily imagine that more profound changes would be produced in it as the result of the earth movements.

The table following shows the change in the quality of coal as the result of the above forces. It also shows the change in character as the mountains, the centre of enormous dynamic forces, are approached.

TABLE OF CHANGE. (1)

	Moist.	Volat.	Fix.Carb.	Ash.
Redcliff near Medicine Hat	20.54%	33.26%	41.15%	5.05%
Ten miles west Medicine Hat	16.82	31.90	43.98	7.30
McPhee Mine	11.35	29.98	51.63	7.04
Taber Mine	7.21	39.18	46.36	7.22
Galt Collieries Lethbridge	4.73	34.61	50.43	9.89

CHANGES IN A VERTICAL DIRECTION are also noticeable in the Alberta field. This is known as the law of Hilt (2) who pointed it out in 1873. Its operation may be seen from assay examples from

(1) Dowling,D.B."Coal Fields and Coal Resources of Canada" 1915.
(2) Hilt, Carl, "Ann.Assoc. d'Ingenieur de Liege, 1873, p 287.

the seams in descending order, the last sample being taken from the base of the Kootenai Coal Measures. The following table illustrates this fact:

TABLE OF VERTICAL CHANGES.

		Moisture	Vol.Comb.	Fix.Carb.	Ash
Smoky River	1.	1.6 %	19.7 %	71.6%	7.4%
	2.	1.7	18.4	73.5	6.3
	3.	2.9	14.8	80.1	2.2
Athabasca Riv.					
Moose Crk.	1.	8.78	31.83	47.16	12.23
	2.	2.67	21.5	72.42	3.86
	3.	4.1	22.28	58.1	15.58
	4.	0.7	15.92	71.1	12.3
McLeod Riv.					
Mnt.Park Mine	1.	1.69	27.8	63.1	7.1
	2.	6.1	26.8	52.53	14.25
	3.	1.4	23.6	55.11	19.43
	4.	2.16	22.1	70.86	4.32

For the determination of the RATE of the downward loss of Volatile Matter, these samples are too few to base a general conclusion upon. They show however the application of the law and a maximum rate of about 5% per hundred feet depth, but it is not at all uniform. Exception is shown in the table and many exceptions are noticeable in the limited number of samples that have been taken in the above mentioned areas. This in part

is due to the condition of the coal being surface samples. But other causes like folding and faulting and the nature of the original ingredients of the mother of coal, play an important part. Coal beds made up largely of spores, resins, waxes, etc, yield more gases than coals derived from woody material. On the other hand coal, near regions of great folding or faulting, would show less volatile matter than the average owing to the relief the fold or fault gives to the pressure. The fault offers an avenue of escape for the gas.

The Energy developed in Crustal Movements is enormous. It varies in degree and intensity in different regions. This is exhibited in a section extending from central Alberta to the mountains. In central Alberta the strata is thrown into gentle wave-like undulations. At the Tofield Mine, where the writer made a careful topographic map of the surface of about three square miles and boreholes to test the coal, the above conditions exist. A gentle dip of about ten feet to the mile was also found, to the southwest. Nearer the mountains sections along the Bow, the McLeod and the Athabasca Rivers show much more pronounced folding. This is

due to their being nearer the centre of the region of greatest dynamic activity. The last and final stage of the energy exhibited is to be found in the mountains themselves. There we find not only individual beds frequently faulted, folded and contorted, but whole systems of rocks thrown into folds and faulted so that strata of Carboniferous times rests on Cretaceous. In this case the systems as a whole have been broken into fault blocks of great thickness, probably 5,000 to 10,000 feet and considerable width, 5 to 20 miles. These blocks have been lifted to great heights. The present mountain tops in the coal areas on the Athabasca and McLeod Rivers are about 7,000 feet above sea level and 4,000 to 5,000 feet above the present valley levels of the Rivers. Not only were the blocks elevated to great heights but they were pushed forward bodily till the older strata Carboniferous is now resting on the newer Jurassic and Cretaceous. This condition exists almost uniformally from the boundary to the Athabasca and northward.

The work performed by this energy is the transformation of the peat material to the more advanced ranks of coal. It affects both the physical and

chemical nature of the material. In this respect it constitutes true metamorphism. It has changed both the physical and chemical constitution of the vegetable sediments.

PHYSICAL AND CHEMICAL EFFECTS: These are not so well known as in the fermentation process. Chemists have not separated, as yet, all the chemical compounds that exist in coal. The Proximate and Ultimate analyses are mere conventions and throw but little light upon the combinations of the various elements, carbon, hydrogen, oxygen, nitrogen and sulphur. They show clearly however that the change has been progressive from the lowest grade of coal to the highest.

Many theories have been advanced to account for this difference in the various grades of coal. These we need not do more with than mention as they are discussed fully elsewhere (1). The theories are:

1. Differences in the kinds of vegetation from which coal is formed.
2. Climatic differences in the various periods or regions.
3. Relative length of time since deposition.
4. Differences in the kinds, in the limits of

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(1) The Origin of Coal, D.White, Bull 38, p 96, U.S.G.S.

activity and in the products of bacterial action in past ages.

5. Enrichment by bitumen, etc, from other sources, especially from deeper-seated rocks.
6. Great differences in depth of burial beneath other formations.
7. Changes due to chemical reagents in subterranean circulation.
8. Heat effects of intrusive rocks.
9. Porosity of beds overlying the coal.
10. Escape of volatile matter through joints in the coal and other rocks.

PHYSICAL CHANGES: The first effect of this is the explusion of the water. With this goes also the methane CH_4, some carbon dioxide CO_2, and the soluble compounds that may have been formed in the fermentation of the vegetable material. From a mass of peat containing 90% of water it is reduced to 40% in low grade lignite, in the consolidation of the material. The expulsion of the water is progressive from the peat to anthracite which contains less than 3% water. The density of the material has become greater as shown by the specific gravity. Lignite is about 1.2, bituminous is about 1.4 and anthracite 1.55. The

appearance has changed from a dull amorphous lignite to a bright, shiny, lustrous anthracite with hardness almost of rock.

TEMPERATURE: The rock temperatures observed in the explored depths of coal fields does not point to high temperatures. The volatile matter may have been driven off without any great rise in temperature. It is certain that many of the organic compounds of coal are unstable and subject to change under high pressure. There is however but little definite information as to the real conditions of the distillation of coal by geodynamic influences. In the beds where the loss of volatile matter is far advanced it is now not easy to say whether it is due entirely to pressure without the generation of much heat or to heat due to intense strain or to both these causes.

CHEMICAL CHANGES DUE TO METAMORPHISM: Plant material is made up of carbohydrates and proteins. Of these the proteins are the first to be resolved by the micro-organisms and restored to the general fund of matter in circulation. The carbohydrates more strongly resist decomposition and so it is upon them the dynamochemical process mostly reacts.

They fall into many classes, including cellulose and resin-wax material.

THE RESIN-WAX material being stable compounds would show little or no chemical reaction as in the bio-chemical process.

THE CELLULOSE is of many kinds and much more unstable than the resin-wax material. As they comprise the woody material of the plant they naturally suffer compression with the explusion of water and gas. This is progressive and well illustrated in the following table:

	Moisture						
	Mine	Air dried	C.	H.	S.	N.	O.
Edmonton coals Wood			50.	6.0		2.	42.0
Strathcona Mine	22.7	18.2	62.9	4.5	0.4	1.3	19.5
Parkdale Mine	22.5	18.9	65.3	4.6	0.4	1.2	17.6
Standard Mine	23.5	19.8	65.6	4.5	0.4	1.3	20.1
Belly River Coals							
Mine at Taber	13	11.7	64.5	4.7	1.4	1.5	13.8
Mine at Lehtbridge	8.4	7.9	66.5	4.9	0.8	1.7	15.1
Kootenai Coals							
Coleman	2.0	0.6	72.6	4.3	0.6	1	5.3
Hillcrest	3	1.3	70.4	4.2	0.6	1	8.5
Bellevue	0.9	0.2	71.5	4.3	0.8	1	6.9
Bankhead	1.1	0.5	76.6	3.6	0.6	1	4.1

At the initial stage of the process Oxygen comprises over 40% of the woody material. At the nearly

devolatized state of anthracite less than 2.5% is oxygen. As the original oxygen is more and more nearly eliminated the heat efficiency of the coal increases.

It would seem clear that the natural history of the plant material from the time of its existence as protoplasm to the diversified complex known as coal, is one of carbon condensation. In proportion as they are attacked by destructive agencies the residue tends to constitute itself into a complex of increasing resistance.

Chapter VI.

PREPARATION OF THIN SECTIONS OF COAL.

For the Microscopic Examination of coal there are two methods of preparing thin sections. The first is that of cutting thin sections on a microtome and the second is that of grinding them the same as for thin sections of rocks. The following is a brief description of these methods.

MICROTOME SECTIONS.

Samples are best secured fresh in the mine at the face where mining is going on. These samples are easiest of treatment and give the best results. The face should be cleaned and carefully examined to note differences in the coal. The coal will show as charcoal, dull amorphous material, and bright glance. A measured section of the face showing the thickness of each of these, and the partings, if any, is necessary. All the grades of coal that presents a a difference in appearance to the naked eye may thus

be secured for examination under the microscope. The samples should be taken with due regard to correct orientation in the seam, in order that they may be studied in relation to each other in a three dimension space. They will be either vertical cross, vertical longitudinal or horizontal longitudinal, of the face. Immediately upon taking and making orientation they should be wrapped in paper and placed in air tight sealer or tins. In these they will keep indefinitely.

PRELIMINARY TREATMENT is necessary in order to secure cuttings of coal thin enough to examine under the microscope. The treatment softens and demineralizes them so the knife will cut them. For coal from the seam mined at Edmonton and Clover Bar it was found sufficient to treat it a month with equal parts commercial hydrofluoric acid and 95% alcohol. Sodium or potassium hydroxide of greater strength than one tenth normal (N/10) broke the samples into powder due to their strong hydrolizing power. Hydrofluoric acid alone gives the least change in the coal.

CUTTING may be done wet or dry according to the microtome in use. If the object is imbedded in

paraffin it will be cut dry, if in celloidin it will be cut wet. It is well therefore not to choose an instrument that is adopted to only one or other of the above methods, better an all round instrument. Amongst those fulfilling these conditions is the Thoma sliding microtome or the Minot rotary is good.

IMBEDDING: is employed for two purposes.

1. It enables us to surround an object too small or too delicate to be firmly held by any instrument, with some plastic substance that will support it on all sides so that it may be cut into very thin slices without distortion.

2. It enables us to fill out with the imbedding material the natural cavities in the object so that the internal structures may be cut in situ.

These ends are attained in one of two ways. The object to be imbedded is saturated by soaking with some material like paraffin that is liquid while warm and solid when cold, or the object is saturated with a substance like celloidin which is liquid as long as the solvent is retained but becomes hard when evaporated. These are the two important methods of imbedding.

IMBEDDING MANIPULATIONS in paraffin. The object

is placed in a bath in molten paraffin for 3 or 4 days so that it penetrates the mass. For coal it is better just to surround the object with paraffin. In this case a small paper tray or watch glass is filled with molten paraffin and the object dropped in. The whole is then placed in water to cool rapidly1 When the paraffin is hard the whole mass is trimmed and fitted to the microtome ready for cutting.

The material may be saturated with paraffin by the use of a solvent of paraffin. The object is first saturated with the solvent of paraffin to be used. There are a number of these such as turpentine, benzol, clove oil, toluol, xylol, chloroform, and cedar wood oil. Of these possibly the last two are the best. They penetrate rapidly and do not interfere in cutting if not entirely removed. After saturation the object to be imbedded is placed in melted paraffin and heated till bubbles of chloroform cease to come off.

Cooling the mass is an important point to be attended to and it should be done as rapidly as possible.

SHAPE AND ORIENTATION OF BLOCK TO BE CUT. This differs according as the cutting is done with a

slanting or square set knife. In the first case the block is best trimmed to a three sided prism and oriented so the knife enters at one angle of the prism and leaves at another. For the square set knife the block is best trimmed rectangular and for ribbons or serial sections oriented so that two sides are strictly parallel to the knife edge. If only isolated sections are to be cut it is oriented so the knife starts at one corner and leaves at another. The great trouble is the sections roll.

KNIFE POSITION may be considered under slant and tilt. These are best determined by trial for each block. Paraffin sections are cut dry, that is the knife is not moistened with alcohol or other liquid. With celloidin the knife is flooded, i.e., the knife carries all the alcohol or other liquid that will hang to it and the section floats off into it as cut.

CLEARING AND MOUNTING PARAFFIN SECTIONS. The cut section is transferred to a slide and the paraffin got rid of by some solvent such as xylol or toluol. The excess of xylol is removed by blotter or cloth and a drop of Canada balsam placed on the section and covered by a cover glass.

To dehydrate these sections they are transferred to xylol to remove the paraffin and then they are stepped up through alcohol and xylol and mounted in balsam in the usual way.

CELLOIDIN Imbedding Manipulations: may be carried out either hot or cold. The object need not be cleared before imbedding though it is best to do it. Some of the coal tried like the Dawson would not stand clearing with ether and alcohol as it swelled disastrously. In this case the samples were put in cold celloidin and allowed to stand several days though it would be better if allowed to stand a month or so.

HARDENING of the celloidin may be done by evaporation or by chloroform. If the object is put in a small tube with a loose fitting cork and enough celloidin added to cover it three or four times, when the mass of celloidin has shrunk to about one third its original volume the object may be removed and placed in chloroform to harden further. An hour or so in this is sufficient. Better still is to place the object in a dessicator with a few drops of chloroform and allow hardening to proceed in the vapor of chloroform.

To fix the celloidin block to the microtome, take a small block of wood that fits into the microtome holder and cover with a layer of celloidin which is allowed to dry. Upon this place the object to be sectioned and pour a few drops of celloidin over it. It is now ready to put in chloroform to harden. When hard it is ready to cut.

Paraffin blocks are fastened to the microtome by using melted paraffin and allowing to cool.

The sections cut in celloidin are now transferred from the knife to weak alcohol, 50% to 70%, the absolute, and finally xylol. The sections are next transferred to a slide covered with Canada balsam and a cover glass.

The Bleaching of the sections may be done by Schultz solution or Javel water (Chlorine water), upon removal from the knife. They are then carried through as above described.

GROUND SECTIONS.

It is impossible to obtain large sections of coal cut with a microtome, yet the larger sections are valuable in obtaining a general idea of the components in their wider relationships one to another. Recourse was therefore made to ground

sections in the endeavor to secure larger sections. The rapidity with which the coal gave up its moisture soon filled the sections with air checks along which the coal exfoliated and so soon spoilt the section. To overcome this an endeavor was made to infiltrate the coal with Canada balsam dissolved in carbon disulphide. Time, however, did not permit experiments to be completed to demonstrate if such a method was a success. From the experiments made better results were obtained than without the treatment. It is possible to find a suitable medium to infiltrate the sub-bituminous coal and so grind them to the required thinness. Where obtainable these larger sections show the materials unchanged by any chemical action.

The process of grinding thin sections of coal is difficult owing to its soft, friable nature. The blocks selected were carefully oriented and cut to about 3/4 inch square in size. The surface from which the section is to be cut is ground down and polished so that abrasion marks are no longer visible under the medium power of the microscope. The grinding may be done on a glass or iron plate with emery powder, or on a revolving disk with emery or

a carborundum disk of the finest grade possible. A moderate speed is best and water used at first. Not having a carborundum disk, finishing was done dry on a fine oil stone and finally a carborundum hone and polished on a chamois skin. The polished surface is next cemented by Canada balsam to a slide. As it is not possible to transfer thin coal sections, a slide on which the specimen is to remain should be selected. The natural paper-filtered Canada balsam should be hardened by heat on a hot plate or air or sand bath before using. Experience soon teaches the correct degree. It is such that a part removed on a toothpick and cooled can be just barely indented with the nail. If of greater hardness it is liable to be brittle. Slide, block and balsam are warmed to the same temperature and when molten the balsam is smeared on the slide and some on the polished surface of the block and then the block is placed upon the slide, polished surface down. Care should be taken to remove all air bubbles by pressing the block as closely as possible to the slide. It is best to let the section stand for a few hours before grinding. The grinding is carried out as above described till desired thinness

is reached. Finally after thoroughly drying in the air the specimen is covered with Canada balsam and cover glass in the usual way.

CANADA BALSAM: For immediate use have balsam dissolved in ether or carbon disulphide. The balsam is heated in a shallow dish till of sufficient hardness when cooled in water. This should be so as just to take the impress of the thumb nail. Break up and dissolve in above liquids. If the balsam thus prepared is too hard, more or less soft balsam may be added to it. Fifteen minutes should be sufficient for the material to harden.

MACERATION PROCESS: This consists of treating small pieces of coal with nitric acid in which is dissolved potassium chlorate. The solution ordinarily used is a saturated solution of the chlorate in water to which is added nitric acid to make about 20% of the whole. Results may be looked for in five days and then the process further continued in accordance with the degree of oxidation desired. If carried on long enough all ingredients are finally oxidized. The method is usually referred to as Schulze's. To determine the point when oxidation has progressed far enough, a fragment

is rinsed in water and then a few times in small quantities of 50% alcohol. To last rinsing in which is still the fragment, a few drops of strong ammonia hydroxide is added. It is now watched and when the fragment is dissolved and disintegrated to the desired point the liquid is poured off and quickly washed in water. It is then washed several times in changes of 50% - 60% alcohol. When thoroughly washed it is kept for reference in alcohol to which is added a few drops of hydrochloric acid.

With the treatment as above indicated, the woody material or cellulosic remains usually reached the right stage in about five days. The strong ammonia would then dissolve out most of the cellulosic remains and leave behind the resin, spore and pollen covers, cuticles and charred fibres. As already mentioned the process is capable of any degree of completeness by allowing time for the oxidizers to act. The grade of coal under treatment also makes necessary changes in the time of treatment. The higher the grade, the longer time being necessary. Samples of debris glance and charcoal from Black Diamond Mine were digested in Schulze's solution from December 17th to January 4th and on

treatment with NH_3OH the glance and debris entirely dissolve and charcoal leaves only white gelatinous substance. That is, the charcoal is made up of material that is difficult to oxidize. Other samples treated longer completely oxidized and left only particles of resin behind.

Chapter VII.

MICROSCOPIC STUDY OF COAL.

Before attempting to prepare samples of Alberta coal for microscopic examination the methods employed by Jeffrey and Thiessen and Lomax were studied. On trial their methods were found unsuitable to coals here. It was found necessary to greatly modify them to suit the coals. The method finally adopted was the result of repeated trials under varying conditions. Some easily hydrolizable substance in the coal gave the greatest trouble. The old method of grinding sections from sub-bituminous coal by means of a lapidary's wheel or emery dust did not prove satisfactory owing to the rapidity with which the coal gave up moisture and the resultant checking of the sample.

To correctly interpret the observations a wide knowledge of other branches of science is essential. A knowledge of Botany is necessary

that the structure and constituents of plants living and fossil might be understood. A wide knowledge of Chemistry is essential to understand fully all about the material that goes into the make-up of coal and the changes these undergo in the process of coal making.

The preparation of thin sections was described in the preceding chapter and from a microscopic examination of these we can accurately determine the structure of coal. We can decide if the particular coal is made up of wood and woody remains, debris, or spores and their remains.

In no case is coal found to be homogeneous, it is laminated in appearance due to bands of dull and light coal. In well defined areas within the coal are to be found considerable resinous material.

RESULTS OF MICROSCOPIC STUDY.

The samples of coal examined were from the Dawson, the Daly, Twin City and Black Diamond Mines near Edmonton. These were found on the whole to be much alike as the photographs will show. A number of photomicrographs are appended that a comparison may be made of living woods, fossil woods and these coal sections on the one hand and bituminous

shales and cannel coal on the other. The photos of the blocks of coal show the main features to be seen in coal by the naked eye.

THE WOODY CONSTITUENTS.

The wood of the Edmonton Coal has suffered considerable change. Compression has changed the form and texture to almost unrecognizable conditions. This is seen by comparing Plate VI, the living woods, with Plates VIII and IX, which show sections of the coal. Plate VII shows spores of the Lycopodium a living club moss. It shows also fossil wood in cross section and longitudional that is instructive when compared with coal. From these we can see the size of the original cells and the resinous contents, the thickness of the cell walls, the size of the annular rings and the proportion of spring wood to summer wood.

Plate VI shows sections of living wood as cedar, spruce, tamarack, fir and pine which may be found in most peat bogs. In the wood parenchyma the resin cells are mostly well filled with resin. The Medullary cells are also more or less filled with resin. The cells are to be seen well rounded and proportioned.

In the petrified wood shown on plate VII much the same conditions are to be noticed. Much of the original form and normal texture of the wood is to be seen. Through change and loss the thickness of the cell walls is much reduced. However the elements are shown in their true relations as to form, location and number. The layering of the cell walls is retained as seen in the bordered pits.

In passing to Plates VIII and IX we pass to the sections of the coal. Ordinarily the woody parts are readily recognized through the woody structure itself. The cell walls are distinguishable although the cells have been compressed and reduced to a very great degree. The cells are no longer well rounded, with well defined canals but in most cases flattened out and crushed in. The cells of the spring wood are flattened the most and often appear as a tortuous layer in the more resistant summer wood. In the living wood the summer wood comprises the smaller part of the section but in the coal sections the spring wood occupies by far the smaller space. The resin content has suffered little change in form. As the wood itself has suffered a great loss and reduction in metamorph-

ism, the resinous content of the coal appears now very large. Besides showing compression and reduction, the wood shows shifting along the spring wood. It thus must have been in a soft, plastic condition.

THE FUNDAMENTAL MATTER.

This is a product of the bio-chemical or fermentation process and serves as a binding material in the coal. The other components of coal may be said to be embedded in it.

As mentioned under decomposition all destructible plant ingredients such as protein, starch, sugar and ground tissue were the first to dissolve and disappear. The more resistant parts remain as a residue. Of these the important ones are cellulose, cuticles, spore and pollen covers. The fundamental matter itself consists of these, which being in a plastic state fill all interstices in the harder parts. This mixture, it appears, is bound together by cellulosic debris which exists in a gelatinous condition in the mass.

Sometimes in this fundamental matter exists a substance that gives the whole a black appearance. This seemingly consists of minute fragments of

charcoal. The proportion of the embedded material to the ground mass or fundamental matter varies, sometimes being more and sometimes less. In one part the resin is aggregated and in another the exines or cuticle.

SPORE EXINES.

Plate VII shows the spores of Lycopodium. These are called tetraspores because they develope as four cells out of one from consecutive cell division. This is true of all Byrophytes (mosses) and Pteridophytes (ferns). During the growth the exines develope and harden to this tetrasporic grouping. When mature and shed by the plant they retain the shape showing the mutual union of the inner edge of the four spores. It is called the triradiate mark and serves to identify it. Since its contents of vital matter is long since gone, it is best now called a spore exine. As seen in cross section it appears as a compressed or flattened ring, or it may be broken. The wall is generally thin, in color a light yellow with glistening appearance and homogeneous throughout.

Pollen exines are not easy to distinguish from the spore exines. The walls are thinner and

of a lighter color. The sculpturing on them is reticulate and in case of some their outline is peculiar.

CUTICLE.

The cutinized membrane of the epidermis can be seen in sections cut crosswise to the bedding. They are the waxy or resinous portion the plant had for protection from outside attack. They may represent leaves or various stems. They are light yellow or almost white in color, to red and dark brown and of any length, long or short and thread-like in appearance.

RESIN PARTICLES.

These are always present being derived from the decayed stems, roots and bark. As seen in Plate VI the bark is very resinous in some trees, and affords a great variety of shapes and sizes of resin. In the woody parts of the coal the only source of resin is from the parenchyma and so the size conforms more or less to the enclosing resin canals. In debris the source is from a wider field, so of greater variety in size and form. Leaves,scales and oozings from wounds on trees all add their quota.

In the coal sections the resin is often broken out in the cutting or lost on account of its brittleness. Their color varies from light yellow to brownish and amber color. The particles are often filled with vacuoles or air bubbles. These range from large to small and from few to many. Often one particle of resin is enclosed in another of different shape and color. Resin particles originating in wood fibre are readily distinguishable by the form imparted by the resin ducts, that is they are cylindrical.

CANNEL COAL.

The cannel coal tried was from the Acadia Mine in Nova Scotia. The sections were ground. Macroscopically the coal appears to be uniform in structure, dark and without a lustre. In Plate X we have shown photographs cross-wise to the bedding. The coal is seen to be made up of about equal parts of spore exine and resin particles and ground mass. Megaspore exines are also present.

SPORE EXINES.

These are prominent and abundant in the coal. They are much flattened, some with thin walls and some with thick.

RESINS.

Resinous bodies are present in large numbers. In color they range from a light golden yellow to a dark brown. They are on the whole rather translucent. In size they range from the merest speck, barely visible under the microscope,to quite large particles.

OIL SHALE.

The shale shown in Plate X is from New South Wales, Australia and consists almost entirely of spore exinesgreatly flattened. In the other shale from near Nakamun, Alberta, the exines are more broken and not so distinct in outline.

The oil shale from New South Wales is a good example of spore material forming a bed.

POINTS OF ATTACK.

Other fields presented themselves for attack on coal, from which important results may be looked. Time did not permit of more than a start on some of these.

Polished surfaces may be examined as in metallography.

Maceration with Schulze's solution and examination of remains.

Maceration of microtome sections with Schulze's and process observed under microscope.

Infiltration and grinding.

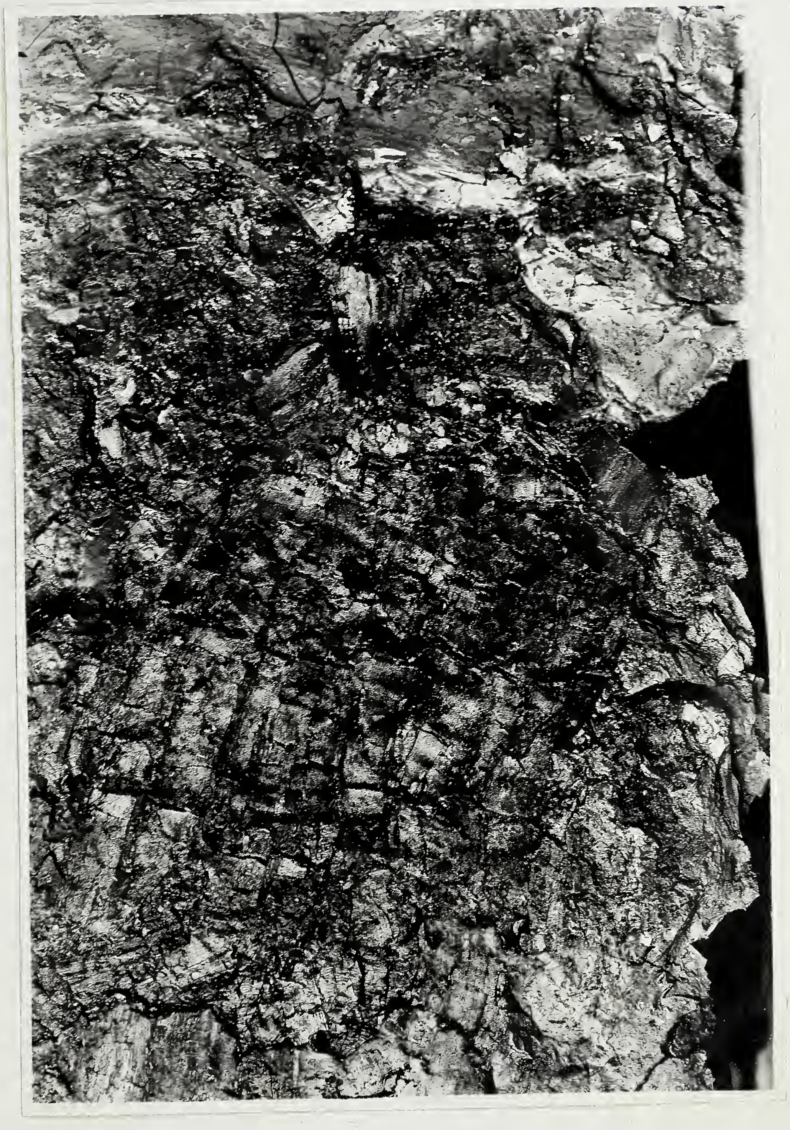
Dissolution in phenol, pyridin, etc and chemical analysis.

PLATE III.

Lump of sub-bituminous coal from Clover Bar Seam, Edmonton, Alberta.

This photograph shows a sub-bituminous coal from Clover Bar, Edmonton Formation, Laramie Age. It is a fragment of coal in which some of the original wood was changed to "mineral charcoal". The carbonized wood or mineral charcoal rests in fine debris more or less macerated or decomposed. More often the charcoal forms a layer surrounding the bright glance layers in coal. It usually has a fine silk-like lustre and it usually retains the appearance and form of the wood fibre. The layer of glance coal is supposed to be the flattened trunk of some tree the outside of which has been changed to charcoal. In the glance the wood has been changed to some humic compound and then solidified. In this process the decomposition of the wood has been complete. It may retain, however, in some instances, the annular rings quite distinct though greatly compressed.

Plate III.



COAL FROM EDMONTON, ALTA. SHOWING "MINERAL CHARCOAL".

Natural Size

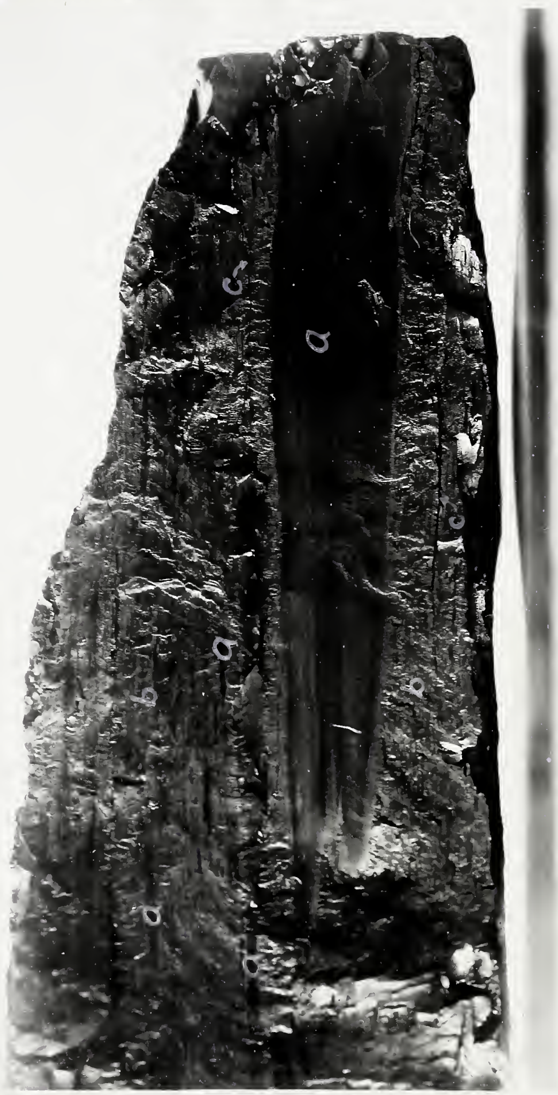
PLATE IV.

Sub-bituminous Coal of Laramie Age.

This is a photograph of a piece of coal from Clover Bar Seam, near Edmonton, Alberta. The jet black lenses and stripes (a) of various sizes represent stems and branches or twigs of trees or shrubs, which after undergoing partial decomposition and softening in the original peat were buried and flattened by the pressure of the overlying strata. The more completely flattened layers represent soft and easily decomposed wood in the peat. The very black ones are those which resisted decomposition and hence show that putrefaction had not advanced far though densely compressed and hardened. In such the annular rings are yet visible. Some of the fragments were seemingly decayed in zones as shown in the ragged or fringed edges of the lenses. The amount of wood that was only partially decayed during the peat formation and now shows as these jet lenses is comparatively large. The duller layers of the coal shown lighter in the photograph (b) is largely composed of vestigal matter, which shows great evenness in bedding. These comprise woods, cuticles, leaves and bark, more or

less completely changed. Cracks (c) due to shrinkage from loss of water are also to be seen. Originally in this was also some very thin flattened pieces of wood, which have been changed into mineral charcoal. These are scattered through the mass.

Plate IV.



SUBBITUMINOUS COAL SHOWING FLATTENED LOG.
Natural Size

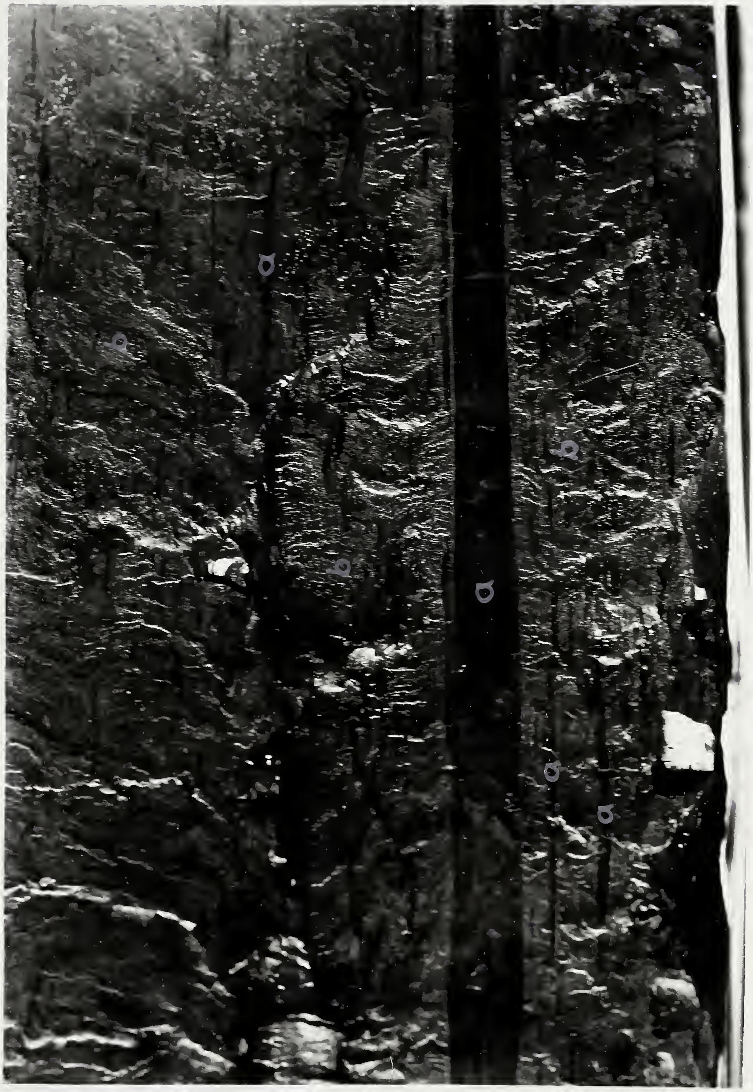
PLATE V.

Sub-bituminous Coal, Laramie Age.

This photograph shows a dark jet-like band (a) near the bottom which probably represents a flattened log. The thin parting line traversing the band possibly represents the line of contact between opposite sides of large woody or cortical cylinders, hollowed by decay and then flattened by pressure. Like the preceding plate the coal is very dense in aspect.

It may be here noted that in respect to the character of the bedding and the included wood and charcoal, the Edmonton Coal of Laramie Age is essentially the same and agrees very closely with the older coals from the Belly River Formation and the Kootenai Formation. This is pretty strong evidence that the higher grade coals like bituminous and anthracite originate in the same way as lignite and sub-bituminous, in peat beds. By being submitted however, to greater metamorphic changes they have reached the stage we now find them in.

Plate V.



SUBBITUMINOUS COAL FROM EDMONTON, ALTA.
Natural Size

PLATE VI.

Living Wood.

1. Tangential section of cedar showing medullary rays filled with resin, at (b); at (a), is resin ducts filled with light colored resin, the dark is air; (c), is wood parenchyma with grains of resin in it.

2. Tangential section of fir showing the medullary rays; (a), filled with resin; (b), is wood parenchyma.

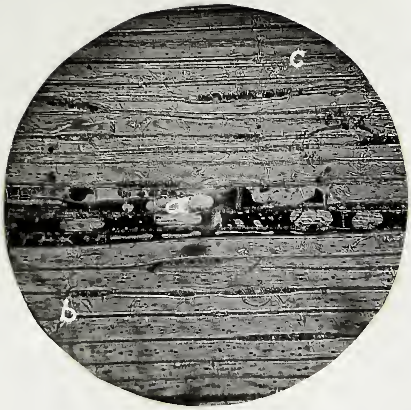
3. Tamarack tangential section showing the ray cells filled with resin as at (a); the summer wood ends at (b), on the one side and spring wood (c), begins on the other.

4. In this the pine is cut tangentially and shows the ray cells swollen with resin at (a); (b), and (c), show the same as in the tamarack.

5. A section of spruce bark showing at (b), a dark resin layer next the wood (c), and (a), light resin layer outside of (b). From (a), outwards in the bark the cells are filled with light and dark resin making a good protection for the tree.

Magnification: (x 50).

Plate VI.



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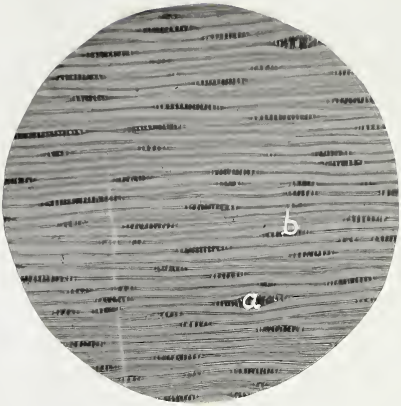

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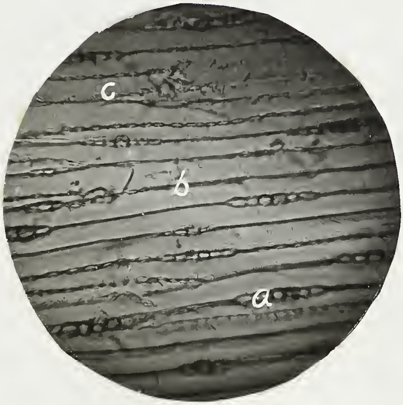

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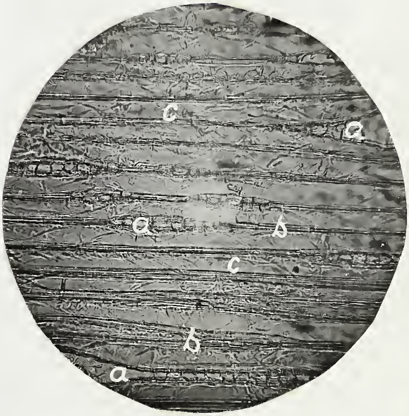

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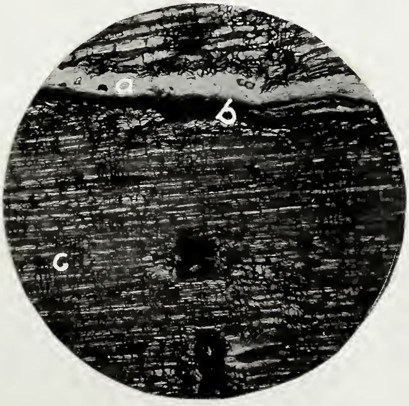

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Plate VII.

I.

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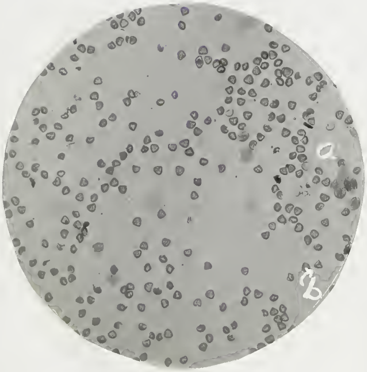

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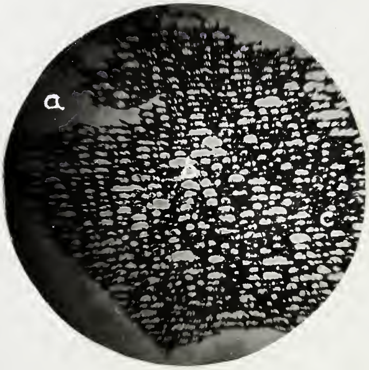

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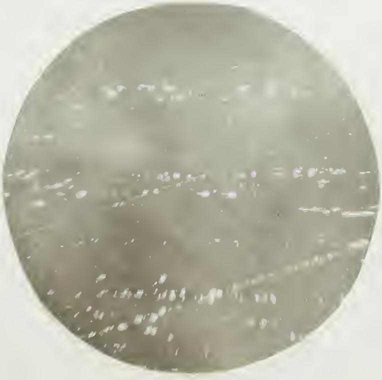

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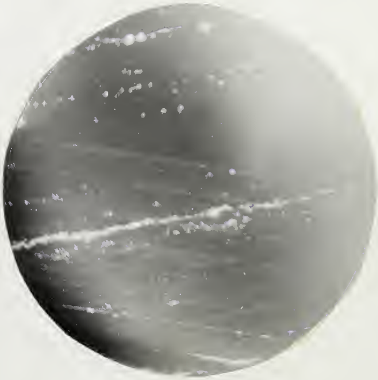


6.

PLATE VIII.

1. Wood all crushed in just faint black lines to represent the cell walls. Resin in layers and cylindrical in shape. There are lighter and darker colored particles with vacuoles. Some resin particles are dislodged in cutting. Occasionally a lighter resin is embedded in larger grains.

2. Dawson charcoal cross section. On either side of section you can see remains of wood cells but flattened and crushed in till walls almost touch. On the lower side is a part of the section where resin has disappeared and only faint traces of cell structure is left. In the centre of the section the crushed cell structure is very plain in which is embedded a great deal of resin both light and dark which is rounded or elongated in shape. Some show reticulated surfaces and some vacuoles.

3. Shows charcoal longitudinal section. It shows lamination in two directions. The cells have collapsed and flattened horizontally, some of the white being resin which is also flattened. Then endwise the section is crushed showing the spring wood crushed upon itself. Within these areas the

resin is granular as if much shattered.

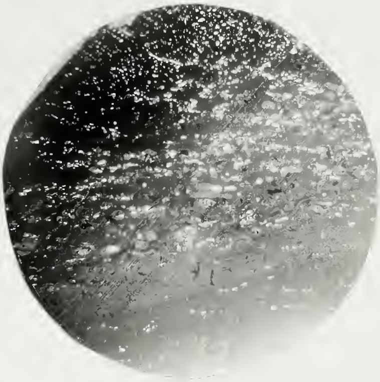
4. The laminated appearance is due to the severe crushing that has flattened wood cells and resin grains as well.

5. Under medium magnification all cell structure has disappeared and mass looks like concrete, the resin particles corresponding to the larger stones. The appearance of the ground mass is somewhat granular.

Magnification: (x 50)

Plate VIII.

I.



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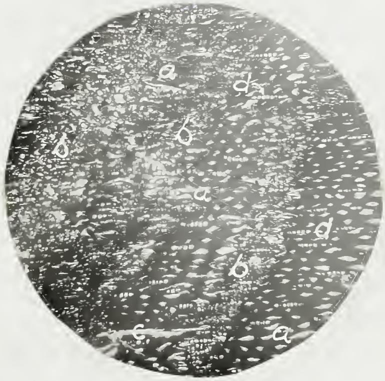


3.

4.

5.

PLATE IX.

1. This is a section cut crosswise to wood from the trunk of a tree that came from the Twin City Coal Mine, secured by Prof. W.H. Alexander. The whole was converted into coal but had retained its original shape in the coal bed. Most of the long thread-like white strips are the remains of the cells on the original wood, all but closed from crushing, as at (c); (a) is a hole in the section; (b) is the homogeneous ground mass with faint black threads through it, the remains of the cell wall. The dark or oval spots as at (d) are resin.

2. Wood cells from Dawson. The laminated appearance is from the collapsed cells. This is a section which shows little resin.

3. Is a very badly crushed section. The cell walls have been changed largely into homogeneous mass with only faint dark threads to show the last remains of the cell walls as at (b). Resin shows dark as at (a) and is distributed unevenly through the mass. Odd cells that were more resistant than others show the cell still as space.

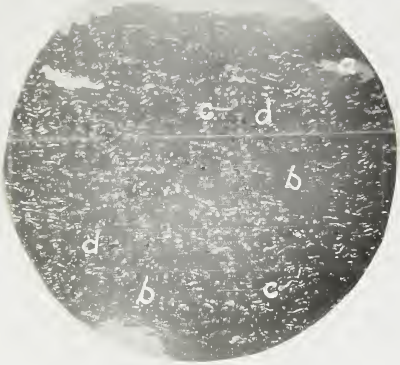
4. The dark mass in the centre of the photo is charcoal, as also lower mass. To the top is long

oval mass block which in the section is granular ground mass of the coal with a strip of cuticle, possibly, that is faintly seen lighter in centre of mass and to the end.

5. (a) Is hole in section; (b) is cutinized cell wall remains; (c) is very much flattened resin. Many long white streaks or cracks show in this section. This section is rich in resin of many shapes and kinds, light and dark, granular and amorphous. Cuticle is present in this section. The section has been very much crushed and only occasionally is a cell recognizable.

Magnification: (x 50)

Plate IX.



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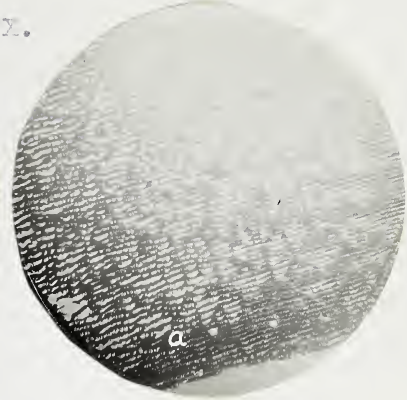

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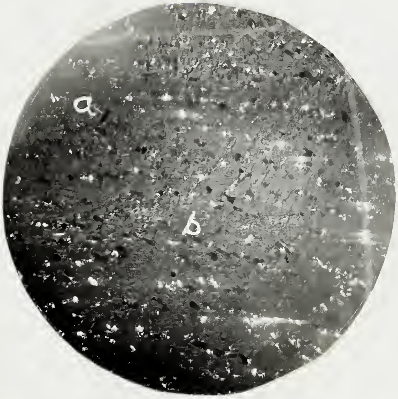

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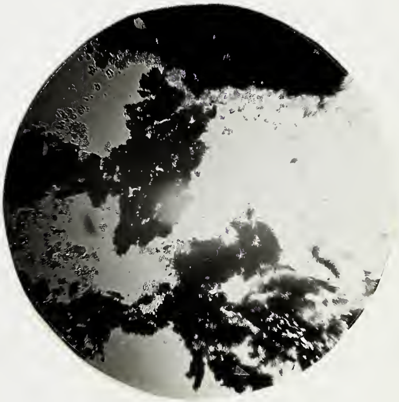

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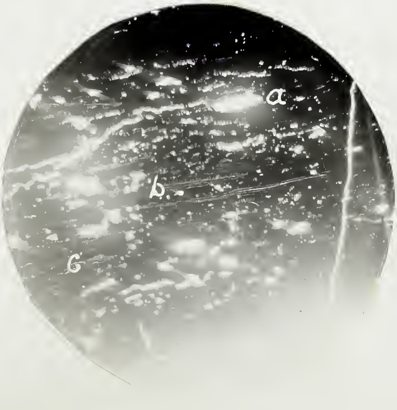


5.

PLATE X.

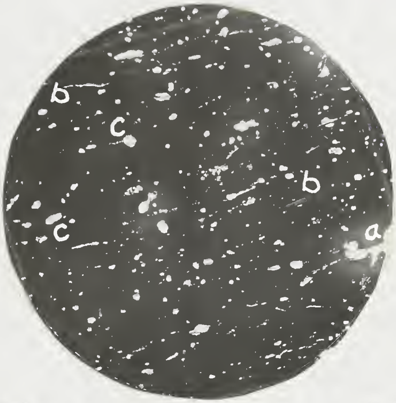
1. Is a ground section of Cannel Coal from the Acadia Mine in Nova Scotia. (a), is a hole in the section; (b), showing very faint light is possibly a megaspore exine; (c), is Resin very translucent and somewhat granular. The white lines, threadlike, are spore coats. A few oval shaped objects, one near (a), showing very faint, are possibly spores. The ground mass under medium power has a fine reticulated appearance. The translucency of the resin and spore covers gives the whole a rather brilliant appearance.

2. Has an indistinct laminated structure. Under the high power each of the white patches shown on the photo is seen to be made up of numbers of spore covers that appear light yellowish in color and quite translucent. Oil shale from New South Wales.

3. Is very similar to No. 2 but the white patches are made up of much broken material. From Nakamun, Alta.

Magnification: (x 50).

Plate X.



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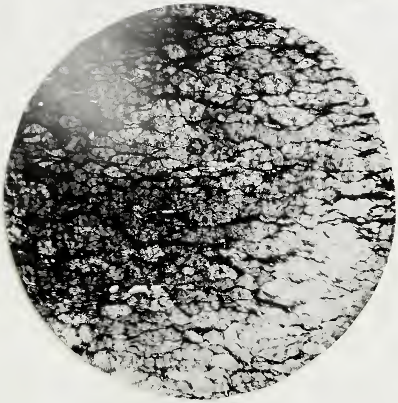

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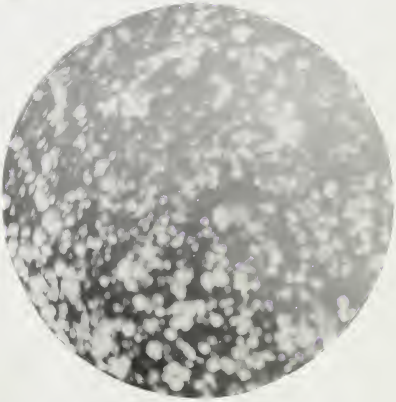


3.

Part II.

COMPOSITION OF COAL IN ALBERTA.

Part II. COMPOSITION OF COAL IN ALBERTA.

INTRODUCTION.

The macroscopic and microscopic study of coal tells a pretty clear story of the structure of coal. We have given the results of a study with the microscope on the vegetable remains to be found therein. In some coals spores and spore remains are abundant,in others,wood remains.

The chemical study of coal is not so simple. The knowledge so far obtained is only qualitative and this of a scattered and fragmentary nature. The methods employed are ill adapted to so difficult a problem. To obtain a quantitive estimation of the components in coal it first has to be got into solution. The known methods so far have failed to do this. This may be due to free carbon in the coal, though in lignite it may be absent as such. The future chemistry of coal will be a study of its chemical constitution and not a multiplying of analysis showing simply C,H,O & N without any reference to the combinations these elements may take in the coal. For this purpose two methods have recently been adapted that

bid fair to give results: These are (1) the use of solvents like phenol, pryidin and analine. (2) Conversion of the coal to recognizable derivatives and an estimation of them as such. The study of coal in this manner is not only of scientific interest but it is of great commercial importance. A solution of the many problems involved in the technical treatment of coal can scarcely be expected without a knowledge of the chemical nature of the substances in the coal. In the past no point of attack was available owing to the lack of a solvent for coal.

Chapter VIII.

SUMMARY and CONCLUSIONS.

The structural composition of coal is well shown in a microscopic study of it which can be supplemented by a macroscopic study.

The chemical composition is more difficult and as yet but little has been done upon it. True, we have empirical analyses but they tell us nothing of its real chemical constitution.

In the past there has been no solvent for coal, while now two or three are available such as phenol, pyridin and analine.

Sampling is of far greater importance than ordinarily believed both in the mine and laboratory.

The proximate and ultimate analysis of coal is of little value for the determination of the chemical constitution of coal. They serve for the present to buy and sell coal upon.

The by-products of coal are many and of great importance where they can be utilized.

Chapter IX.

GENERAL STATEMENT.

In the preceding pages we have seen that in its physical make-up coal is metamorphosed organic matter in the form of carbon, with a greater or less admixture of foreign matter as impurities, such as iron, silica, calcium, etc, existing principally as oxides, sulphides, silicates, carbonates, etc. The organic matter forming coal is the accumulation resulting from the successive growth and disintegration of vegetable matter under water through long ages. This accumulation becoming submerged by geologic changes, was eventually buried beneath successive layers of other materials either deposited from the waters or washed thither by streams. Through the agency of heat and pressure the organic matter was gradually changed into coal. The chemical composition of the several varieties of coal, with their relations to one another and to the vegetable tissues out of which they are formed, are illustrated in the following tables, based on data collected by Prof. Thorpe.

	Wood	Humus	Peat	Lignite	Brown Coal	Coking Coal	Steam Coal	Anthracite
Carbon	50.2	54.8	60.8	67.4	72.8	80.5	86.5	95.2
Hydrogen	6.2	4.8	5.9	5.6	5.4	5.3	5.2	2.5
Oxygen and Nitrogen	43.6	40.4	33.3	27.0	21.8	14.2	8.3	2.3

This is the:-

Mean composition of carbonaceous deposits, the ash being deducted.

That the conversion of vegetable tissue into peat and coal and thence into anthracite is brought about by a diminution in the quantity of hydrogen, oxygen and nitrogen and an increase of the residual carbon, is shown by the following table, in which the proportion of the gaseous constituents to the carbon is calculated, the ash being omitted:

Average for	Specific Gravity	Carbon	Hydrogen	Oxygen and Nitrogen
Wood	0.50	100	12.3	86.8
Peat	0.85	100	9.7	54.7
Lignite	1.04	100	8.3	40.0
Brown Coal	1.15	100	7.4	29.7
Common Coal	1.30	100	6.4	13.4
Anthracite Coal	1.50	100	2.6	2.3
Graphite	2.20	100	0	0

It must be remembered, however, that while oxygen, hydrogen and nitrogen are passing off, a portion of the carbon goes too, not only water and ammonia being formed, but carbon dioxide and various hydrocarbons. The gaseous elements, however, pass off at a greater rate than the carbon and thus the proportion of the latter element is being continually augmented in the residual mass. The existence of occasional seams of

coal almost wholly made up of macrospores and microspores of the great cryptograms of that period may be noticed e.g.,better bed coal near Bradford, England, and white coal of Australia.

Chapter X.

SAMPLING.

The first important matter is to get a portion of the material to be investigated. This should be taken so as to represent a fair average sample of as many thousand tons as it is practicable to procure. The sample cannot be taken too carefully, for this is the foundation on which the entire investigation rests.

MINE SAMPLING: The mine should be studied with a map to guide where suitable places can be selected to take the required number of samples. Four is probably a minimum in any mine and one for each 200 tons shipped per days. Local conditions govern as coal may vary greatly.

The process consists in cleaning the face, cutting the sample by making a groove three inches wide and one inch deep in coal with weight of six lbs of coal for each foot in thickness of seam. This is broken down and quartered. Partings of more than 3/8" thick are discarded. In the process of pulverizing the largest piece should pass a 1/2 mesh and final sample should weigh about 3 lbs. This is placed in a galvanized can and sealed moisture tight. With care this method will reduce differences in moisture to 0.1% and ash to 0.3%

LABORATORY SAMPLING.

The same scrupulous care must be exercised in the further treatment if the analysis is to be representative of the bed of coal or show its commercial possibility.

In the laboratory air drying is first made of the mine sample, then further crushing quickly carried out in a roll crusher or other suitable crusher and sample reduced on riffle to about 1 lb or 450 gms. It is further crushed to pass 60 mesh and thoroughly mixed for assay.

The following minimum weight of sample is recommended for the laboratory: (1)

Size of largest Impurity.	Mine Weight Sample
1/2 inch	75 lbs
3/8 "	30 "
1/4 "	9 "
3/16 to 1/5 inch (4 mesh)	5 "
1/8 inch	3-5 "

The following tables give data that will be of use in sampling coal under varying conditions. It is based upon the "size-weight" per cent of 0.01 and coal containing 5% of ash from slate and impurities:

(1) Sampling of Coal in a Mine, J. A. Holmes, U.S. Bureau Mines, 1911, Tech. Pap. I.

A. Size of slate contained in coal and amount of original sample required to insure the error of sampling less than 1% ash.

Size of slate inches.	Wt. of largest piece of slate lbs.	Original sample should weigh lbs.
4	6.7	39,000
3	2.5	12,500
2	0.75	3,800
1½	0.38	1,900
1¼	0.24	1,200
1	0.12	600
¾	0.046	230
½	0.018	90

B. Size to which slate and coal should be broken before quartering or dividing samples of various weights.

Wt. of sample divided, lbs.	"Inches it should be broken."
7500	2
3800	1½
1200	1
460	¾
180	½
40	2 mesh
5	4 "
½	8 "
¼	10 "

C. Limit beyond which sample should not be divided when crushed to different sizes in laboratory.

Size of Coal Mesh	Should not be divided to less than -- grams.	
2	8,300	
4	1,100	
8	120	Should pass at least 60 mesh sieve.
10	55	
20	3	

Chapter XI.

ANALYSES.

It cannot be emphasized too strongly that in coal we have an extremely complex mixture of organic compounds many of which are easily changed by oxidation and otherwise by exposure to the air. It contains water in such a condition that a part of it is usually lost with the greatest ease. After complete drying, it is excessively hygroscopic, probably more so than calcium chloride. These conditions give rise to variations in analysis far beyond what most analysts realize. The purpose of coal is principally fuel, hence its value is proportional to its calorific power. As we learn more and more what coal really is we adopt tests suitable for individual purposes.

In laboratory practice two methods are employed for coal analysis, viz: (1) Proximate; (2) Ultimate.

PROXIMATE ANALYSIS. The proximate analysis is the method most used in the commercial world. No pretense is made to a high degree of accuracy in respect to the analysis. It is

adopted because usually the results must be had in the shortest possible time. Some constituents of coal can be determined much more accurately than others, hence variations are sure to occur even in the best laboratory practice. These discrepancies are more likely to occur in the determination of the volatile matter or the fixed carbon than in some of the others and unless these facts are borne in mind the whole analysis is liable to be discredited in the eyes of those not familiar with the difficulties peculiar to each determination. For fuel purposes the constituents of coal usually determined by the proximate method are

(1) Moisture;
(2) Volatile Combustible;
(3) Fixed Carbon;
(4) Ash;
(5) Sulphur.

Standard methods for these are given in Blair's Chemical Analysis of Iron, or Technical Paper 8, U.S. Bureau of Mines.

ULTIMATE ANALYSIS.

While the Proximate method may be sufficient for most industrial purposes, it is desirable at times to know the elementary composition of coal as shown in an Ultimate analysis. By this method the organic matter

of the coal is resolved into its chemical elements, viz., carbon, hydrogen, oxygen, sulphur and nitrogen. These elements together with the ash are taken to equal 100%.

It is unfortunate in this method that no direct method has yet been devised for the determination of oxygen. It is estimated by subtracting the sum of the other 5 constituents from 100. This throws all the errors of the other determinations upon the oxygen.

RESIN.

The inadequacy of the above methods of analysis for coal is well illustrated if we consider a substance that is abundant in all coal, namely resin. It forms a large per cent of many coals and yet is reported as coal. Resins are present in almost all deposits of coal and are in some places so abundant as to constitute an appreciable portion of the coal. These resins have been derived, for the most part at least, from coniferous trees that have contributed to the original peat from which the lignites or coal of higher rank were formed.

As ordinarily observed, without the aid of the microscope, the resins consist of very irregular lumps varying from the smallest particles to fragments over an inch in diameter. Generally the larger pieces are scattered in a medium of mingled plant debris, all

cemented in a dark humic matrix. The debris is apt to be more or less distinctly stratified and assorted as to kind, size and state of preservation in the strata of the coal bed. Some layers of coal contain more resin than others according to the kind of plant material forming these layers.

The resins are generally yellowish, brownish or amber colored, translucent and vitriously conchoidal in fracture. As is well known, the ambers of the arts and commerce are merely fossil resins. It is produced by the fossil pines of the rocks bodering the Baltic Sea in Eastern Prussia.

Resin however that is visible to the naked eye is after all insignificant in quantity as compared with the resin in particles of microscopic size contained in layers of coal that reveal no resin at all to the unaided eye. The relative amounts of these resins and resin compounds affect certain important qualities of the fuels. The microscopic resins are numerous in kind and mode of occurrence, having been deposited in the cells and vessels of wood, bark, leaves and seed coats and in the outer envelopes of spores and pollen grains. In the plant world of today they are produced by many different kinds of vegetation. A large per cent of the dry wood of

conifers consists of resin, 1% in pines and 15% in lignum vitae.

The resins and balsams for the most part were held in solution by the essential oils during the life of the plant. Distillation or air drying changes the oil, the whole passing into the solid state and as such is found in coal today.

CALORIFIC VALUE.

The calorific value of a fuel is the total quantity of heat developed by complete combustion of the unit weight of fuel. The British Thermal Unit is the heat unit generally used by engineers. It is defined as the quantity of heat required to raise the temperature of one pound of water 1° F at 60° F. A bomb calorimeter is the most accurate method of determining the heating value of a fuel. The calorimeter should be carefully standardized and a calibrated thermometer used with it. The probable error in such work should not exceed 0.3%. This is a higher degree of accuracy than can be obtained in the usual methods of sampling, which often increase the error. Before the bomb calorimeter came into general use, the heating value of a coal was frequently calculated from the ultimate analysis by Dulong's formula:-

(1) Calorific value in Calories, per gram =
$8080C \quad 34460(H - O/8) \quad 2250S$.

(2) Calorific value in B.T.U. per pound =
$14544C \quad 62028(H - O/8) \quad 4050S$.

In the above formulas C, H, O, and S are the respective proportions of carbon, hydrogen, oxygen and sulphur.

There is a fairly close agreement between the above methods. The variation is from 1-1½ per cent.

Chapter XII.

BY-PRODUCTS OF COAL.

It is almost wholly from bituminous coal that the products and by-products are obtained. Other coals give them but only in a very small way. An outline of these by-products is of interest to the scientific as well as the commercial world. In the utilization of coal three methods are available, viz:

(1) Under boilers and in furnaces;
(2) In gas producers;
(3) In coke ovens.

(1) Under boilers and in furnaces needs no comment as it comes under our observation every day.

(2) In gas producers the coal is converted into gas by blowing air and steam through it. The gas may be burned as a source of heat or it may be used in suitable gas engines as a source of power. The gas thus produced always contains more or less ammonia and coal tar. With a suitable plant these may be recovered before using the gas as by-products.

(3) Coke ovens give very important by-products, so do gas retorts. In the coke oven the gas and

other volatile matter is the by-product while the coke remains behind. In the gas retort the gas is the main product and the coke the by-product.

Coke is the residue left after coal is subjected to destructive distillation. It consists mainly of carbon 85 to 90 per cent and the remainder ash. Anthracite and lignite coals do not make a commercial coke simply because they do not fuse when heated. Many bituminous coals do give off gas copiously that first forms into bubbles in the fused mass and later escaping leaves a light cellular but quite hard coke. It makes an excellent fuel for blast furnaces because in burning it does not crumble to obstruct the blast and it has high calorific power.

Table showing analysis of coal and coke produced therefrom.

	Coal	Coke
Proximate Analysis		
Fixed Carbon	69.8	86.8
Volatile Matter	21.1	.7
Ash	8.2	12.3

USES OF COKE.

Coke finds its most important use in the smelting operations of iron, copper, lead, nickel, silver, etc. Gas coke is used for steam raising and domestic heating.

GAS.

Gas is principally in one of three forms, namely: City gas, coke-oven gas, and producer gas. These vary greatly in composition according to the conditions under which they are made. They are principally used for illumination, heating, power and for manufacturing.

AMMONIA.

Ammonia is a by-product of the distillation of coal and the quantity depends on the amount of nitrogen in the coal of which 14 to 60 per cent is recovered, as ammonia, according to conditions. Ammonia finds a wide use in the arts, science, manufacturing and agriculture.

Cyanides are another product of distillation and have a wide application in mining industries. As prussiate they find uses in dyeing, photography and steel making.

COAL TAR.

Coal tar is of a very variable composition according to conditions under which it is made. According to the apparatus, the coal and method of working the coal tar varies. It finds a wide use as a preservative and fuel. It contains however so many valuable products that it finds its chief use in thickly pop-

ulated countries in distillation for these.

Coal tar also gives the following important products that find a wide use in the commercial world: Benzol, Naphtha, Carbolic Acid, Naphthalene, Creosote, Anthracene and Pitch. The following tables give the many by-products from coal:

Chart Showing Some of the Products Obtained from Coal.

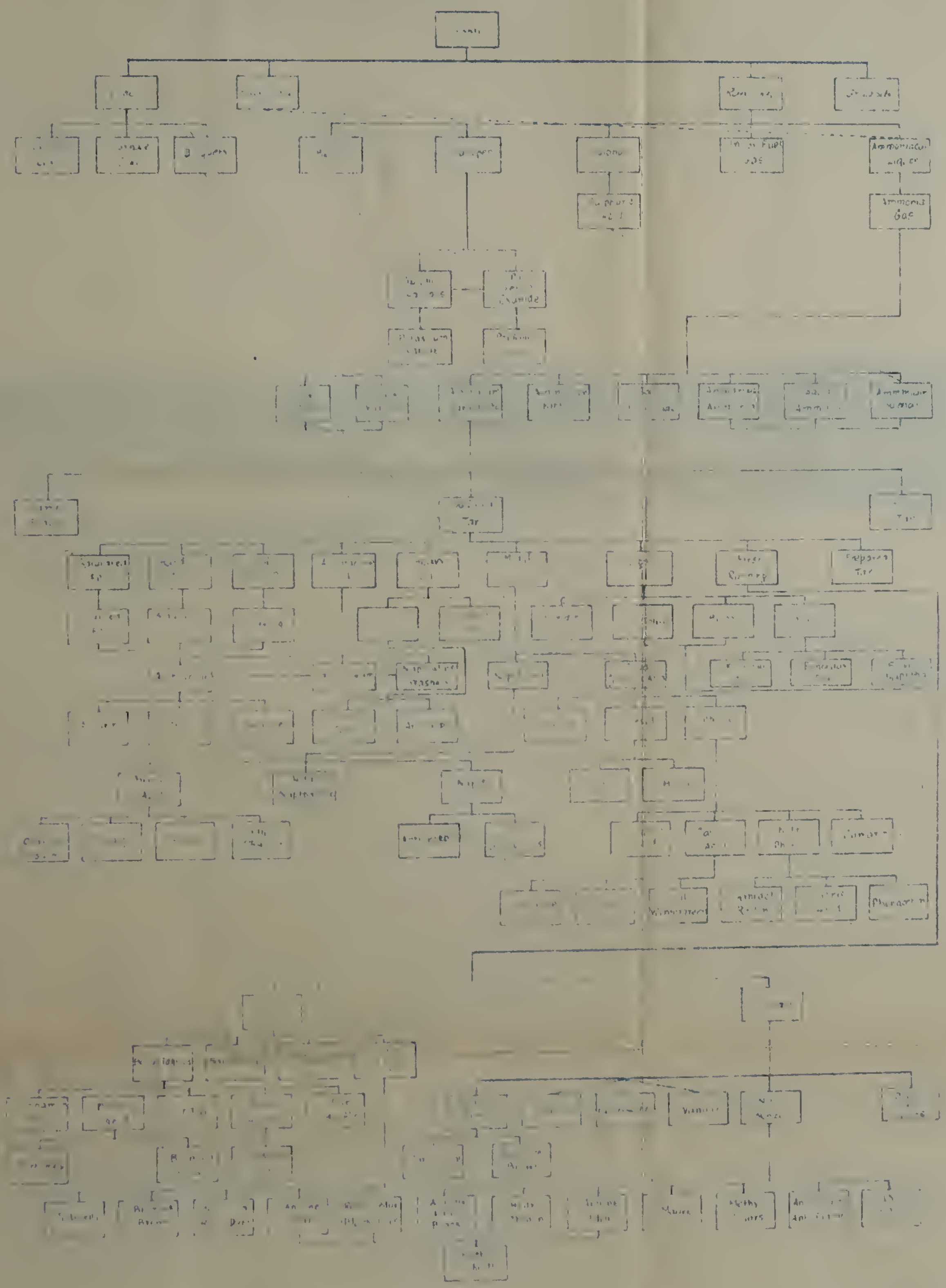


Fig. V .

Genealogy and Uses of Coking By-products.

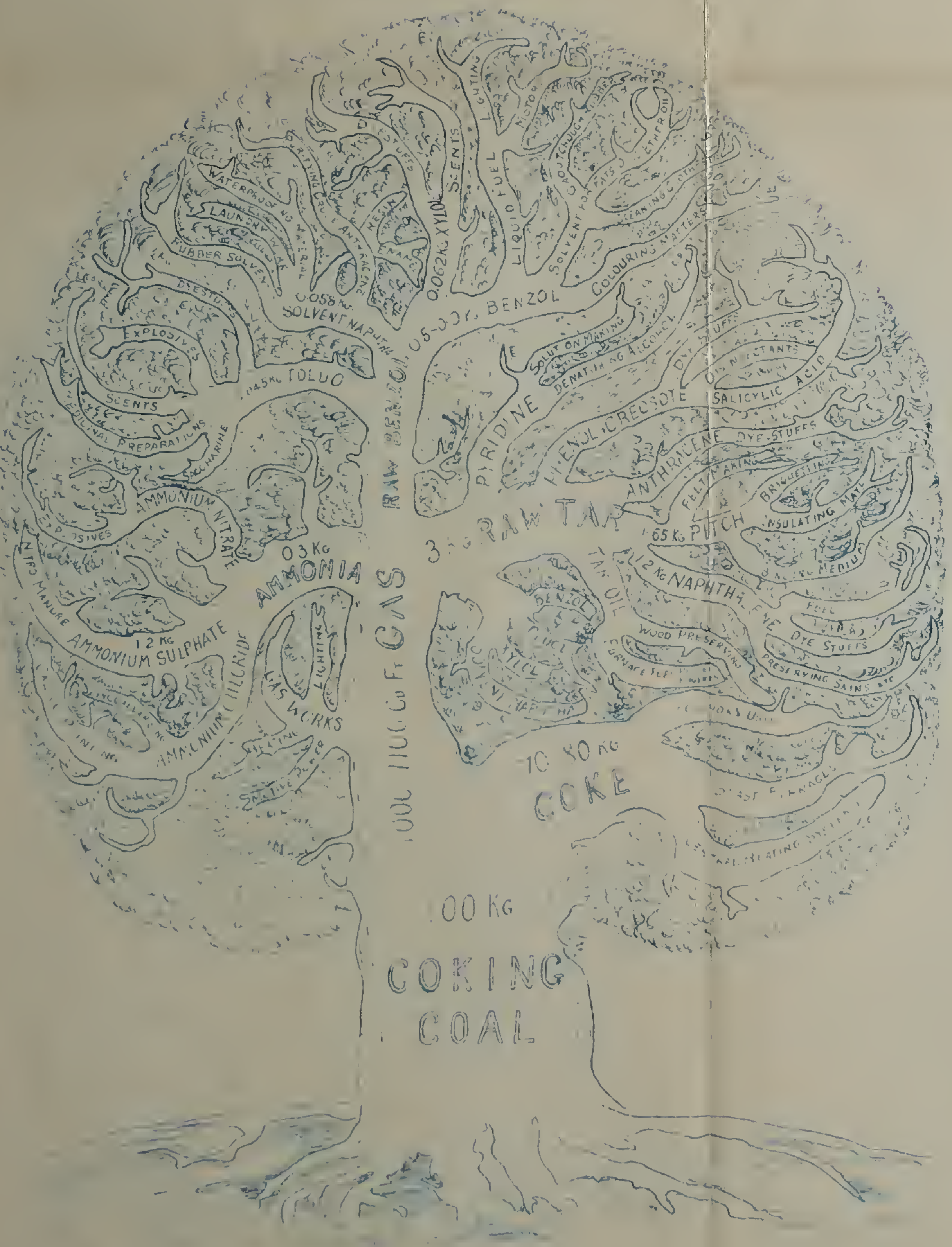
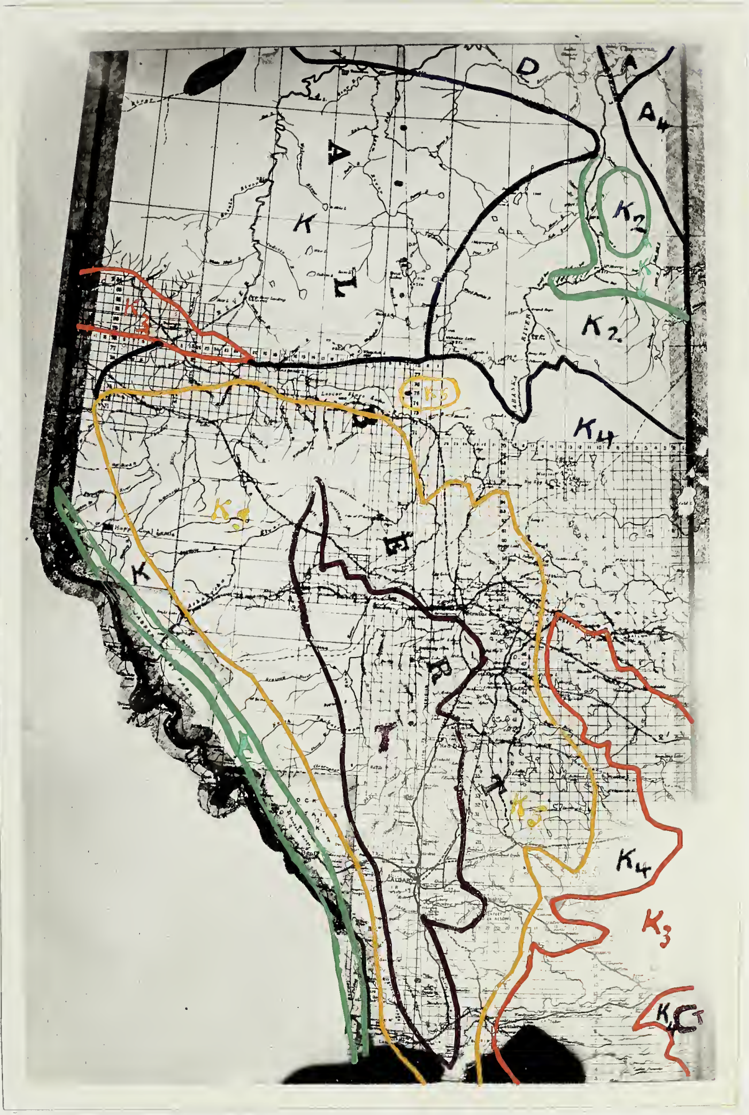


Fig. VI .

Part III.

OCCURRENCES OF COAL IN ALBERTA.

Plate XI.



GEOLOGICAL MAP.

T. Paskapoo.
K4. Pierre-Foxhill.
K2. Benton-Niobrara.
D. Devonian.
A. Pre-Cambrian.

K5. Edmonton.
K3. Belly River.
K. Lower Cretaceous.
A4. Keweenewan.

Part III. OCCURRENCES OF COAL IN ALBERTA.

INTRODUCTION.

A brief description of the geology of Alberta implies an acquaintance with all the work done by the geologists of the Dominion Geological Survey as well as by private explorations. To condense this work is a task made difficult by the extent and diversity of the territory as well as the variety of objects of geological interest. The territory comprises about 255,000 square miles. The geology of such a territory is a history of the works of nature through the lapse of time that began in earliest rock formations and extends to the present. Events of the greatest magnitude and complexity have to be recorded in the dim light of the past. The relative distribution of land and water has been changed in every age, but how, how much, or why we do not know. It is now impossible to accurately map the surface of the earth in Alberta as it was in past ages with its river drainage on lands and its deposits in the sea. Ancient lakes are known to have existed but

their limits have been destroyed and their extent is now a matter of guess work. We know not if the sun shone with the same intensity of heat and light, if the composition of the air was the same, or if the elements were more efficient at their work. In a description of a region like Alberta we must cautiously handle the generalities we have and be content to leave great questions unanswared and many facts unexplained. Among the ideas we have the clearest set forth are Time and Space, both fundamental in geology.

Time as applied to previous ages in the geological history of Alberta is difficult to appreciate. The operations of nature have been exceedingly slow and have been carried on through so many ages, each of such vast duration that the mind wearies sometimes and becomes confused. Nevertheless the geologist is compelled to go backward in time and downward through the rocks to describe rock formations in the order in which they were laid down. His terms, however, are only comparative as upper, middle and lower, or new and old as he has no time measuring rod to apply to the infinite extent of geological times, ages and formations.

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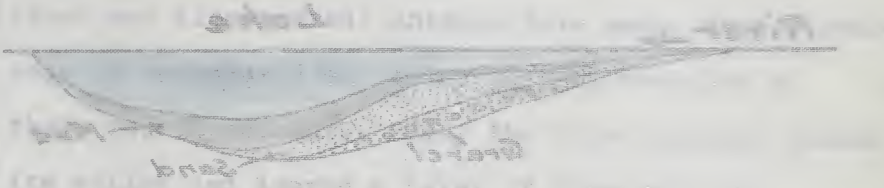
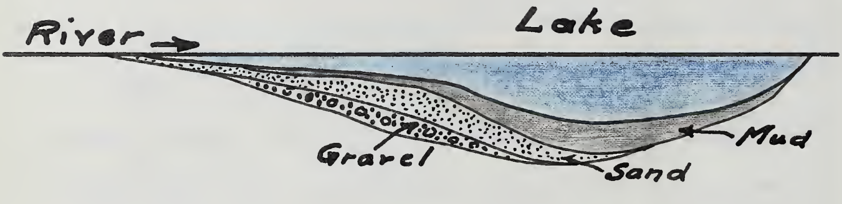

Lake
River
Till
Sand
Gravel

[illegible]

[illegible]



The order of deposition of river borne sediments on the floor of a lake after a recent flood.

After Lapworth.

Fig. VII.

From observation it is evident the same physical forces have operated through all time in the same way we see them operating today. Rivers leisurely delivered their burdens to the sea; forests flourished and disappeared; animals have made their appearance in an orderly manner as plainly revealed by their fossil remains.m Today the Nile annually floods its valley and leaves a layer of fine silt and coarser sand. This fact has been taken advantage of to measure the time it has been delivering sediments into the Mediterranean. Shafts have been sunk to bed rock and the layers counted. In the same manner ancient formations grew, layer upon layer, annually through the ages that we now rudely measure by their several thickness.

Space is the second idea fundamental to geology. The length, breadth and thickness of formations have to be considered. To say the Dakota sand extends from the Peace River on the North, Manitoba on the East, Dakota and Wyoming on the South and the Rocky Mountains on the West, and is from 50 to 1000 feet thick is to gain some idea of the extent and quantity of material involved.

Chapter XIII.

SUMMARY and CONCLUSIONS.

Coal is found in the following four horizons in order from above downwards, viz:-

1. Tertiary;
2. Edmonton;
3. Belly River;
4. Kootenai.

The geological structure is simple.

The stratigraphy is often obscure owing to lack of exposure or bore holes.

The economic importance rests almost entirely with coal, of which the distribution is very wide, the greater part of the Province being underlaid with coal.

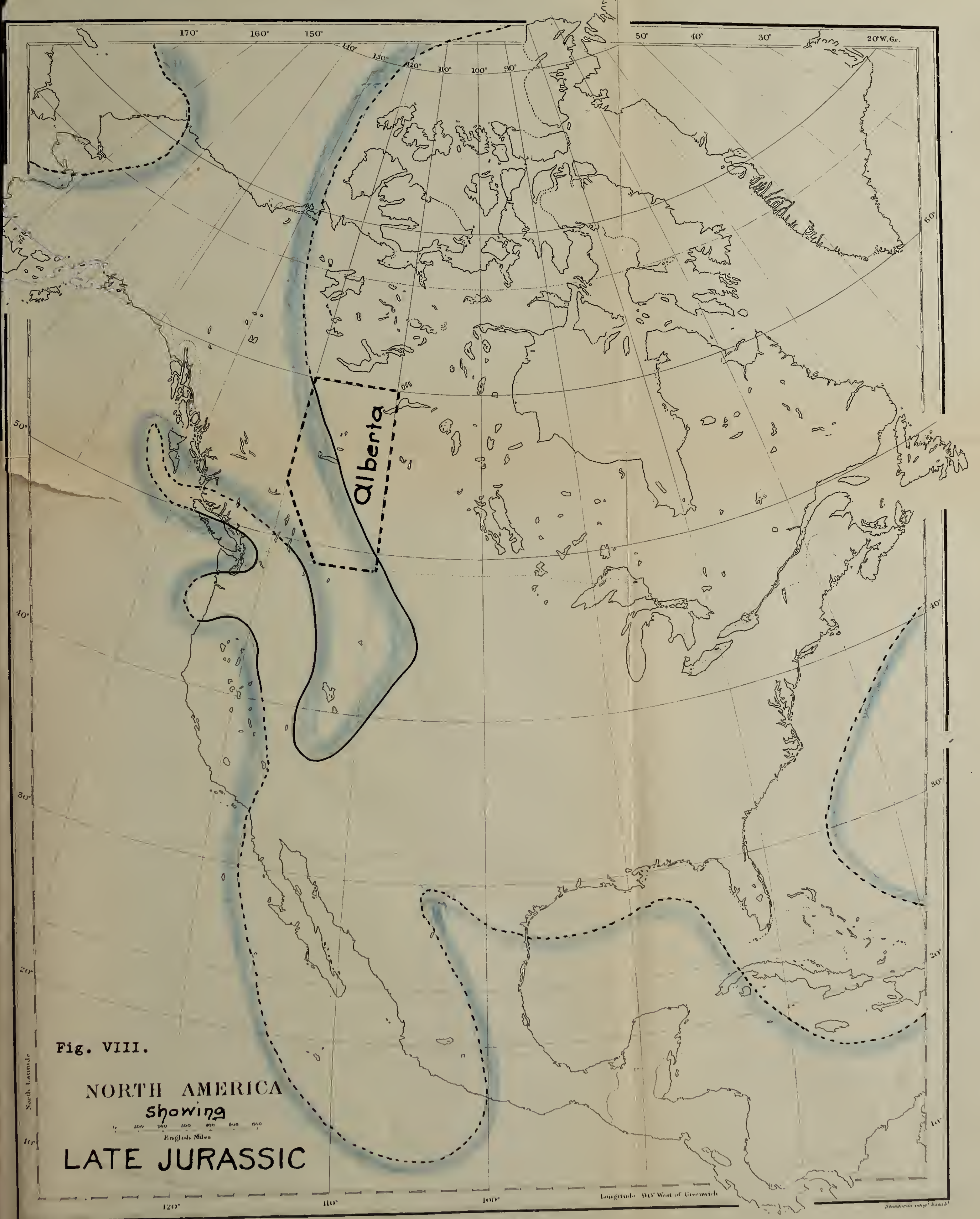


Fig. VIII.

NORTH AMERICA
showing
LATE JURASSIC

London: Edward Stanford, 12, 13, & 14, Long Acre, W.C.

Chapter XIV.

GENERAL GEOLOGY.

Within the area of Alberta are to be found rocks which belong to nearly all the great geological systems from Pre-Cambrian to the Recent. The Pre-Cambrian is the floor upon which the others rest. In order passing upwards, we find Cambrian, Ordovician and Silurian in the Rocky Mountains,in limited extent east and west, but represented from International boundary northward into the McKenzie Mountains of the Yukon. Pre-Cambrian is also found in the northeast corner of the Province. Upon the Silurian rests the Devonian system which is of wide distribution and probably underlies the whole of Alberta. Schuchert (1) represents the middle and upper Devonian seas as occupying the great plains as far east as Lake Winnipeg and northwestward to west of Lake Athabasca and thence down the valley of the McKenzie River (see plate opposite). In this sea was deposited the sediments during Carboniferous, Permian and Triassic and Jurassic times. These attain great thickness in the Rocky Mountains while all information points to a rapid thinning eastward, but the extent is not known. The system consists of a

(1) Paleogeography of Nor.Amer. Bul.Geo.Soc.Amer.Vol. 20, plates 76 and 77.

series of shales, limestones and quartzites.

The next system upward and in order is the Cretaceous. This is widely distributed overlying nearly the whole of Alberta, Saskatchewan and Western Manitoba and far into the United States. The following sections embody the results of observations by geologists:-

I. Southern Alberta by G. M. Dawson;
II. Blairmore Frank;
III. Moose Mountain;
IV. Bighorn;
V. Central Alberta and Saskatchewan;
VI. Peace River;
VII. Athabasca River.

SOUTHERN ALBERTA.

		Feet.
Laramie:	Porcupine Hill beds. Sandstones, frequently thick-bedded and generally comparatively soft, with intercalated greyish and blackish shales and shaly clays. Freshwater	2,500
	Willow Creek beds. Soft sandstones, shales, clays, and sandy clays, generally with a pronounced reddish or purplish tint. Freshwater	450
	St. Mary River beds. Sandstones, shales, and shaly clays in frequent alternations, and generally well bedded. Freshwater, except near the base	2,800

		Feet.
Cretaceous:	Fox Hill sandstones. In some parts of the district well defined as a massive yellowish sandstone, but inconstant, and apparently often represented by a series of brackish water, transition beds between the Laramie and Pierre	80
	Pierre Shales. Natural grey or brownish to nearly black shales, include a zone of pale, soft sandstone in the northeastern part of the district and frequent intercalations of harder sandstones near the mountains. Marine	750
	Belly River series. Composed of an upper or "pale" and lower or "yellowish" portions, and consisting of alternations of sandstones, sandy clays, shales, and clays . .	910
	Lower dark shales. Grey to nearly black shales, frequently with arenaceous shales	800

SECTION FROM FORGETMENOT AND MOOSE MOUNTAIN RIDGES:

	Montana:	(Edmonton . . .	not measured.
		(Bearpaw (Pierre Foxhill)	650
		(Judith River (Belly Riv.)	850
		(Claggett(Lower Dark Shales)	250
Cretaceous:	Colorado:	(Niobrara (Cardium Sandstone	50
		(Benton (Benton	725
	Dakota		950
	Coal Measures, Kootanie		375

BIGHORN COAL BASIN.

Upper Cretaceous:	Brazeau sandstones, shales and conglomerates. Wapiabi shales. Bighorn sandstones, conglomerates, and intercalated shales. Blackstone shales. Dakota sandstones and shales.
Lower Cretaceous:	Kootanie formation (coal-bearing).

CENTRAL ALBERTA and SASKATCHEWAN.

		Feet
Post-Tertiary:	Recent deposits. Sands, clays and silts.	
	Upper Boulder clay. Light-grey sand, and generally, indistinctly stratified clay, containing numerous pebbles of gneiss, quartzite, etc	
	Lower Boulder clay. Dark-grey thick-bedded or massive, sandy clays containing pebbles of quartzite, etc, and numerous fragments of lignite	
	Pebble bed. Quartzite shingle lying in a loose matrix	
Miocene:	Gravels, fine sands, and argillaceous marls, the gravels consisting of quartzite shingle, being sometimes cemented into a hard conglomerate by calcareous cement	270
Laramie:	Paskapoo Series. Grey and brownish-weathering, lamellar or massive sandstones, and olive, sandy shales. Exclusively freshwater	5,700
	Edmonton Series. Soft whitish sandstones and white or grey often arenaceous clays, with bands and nodules of clay ironstone and numerous seams of lignite. Brackish water. Correspond to lowest portion of Dawson's St. Mary series	700

Fox Hill and Pierre:	Brownish-weathering sandstones and dark-grey clay shales . . .	600
Belly River Series:	Soft, whitish sandstones and arenaceous clays, changing towards the east to light-brownish and yellowish sandstones and sandy shales, bottom not seen	

Athabasca River Section.			Peace River Section	
Laramie -			Laramie-Wapiti Rv.sands	
Foxhill sandstone		Montana.	Foxhill sandstone	
LaBiche shales(up.pt.)	700 ft		Smoky Rv. shales	
Unrepresented-			Dunvegan sandstone	600 ft.
LaBiche Shales(Low.pt)	225 "			
Pelican sandstone	40 "			
Belican shale	90 "	Colorado	Ft.St.John shales	700 ft
Grand Rapids sandstone	300 "		Peace Rv. sandstones	400 "
Clearwater shale	275 "		Loon Rv. shales	400 "
Tar sands	140-220 "			

Dakota unrepresented.

The following is a generalized table of the formations represented in the above tables: (1)

---

(1) Dowling Coalfields of Manitoba, Saskatchewan and Alberta.

	Groups	Alberta	Saskatchewan	Manitoba	Montana	Dakota	Kinds of Rocks	Character of Fossils.
Tertiary	Oligocene	Oligocene	Oligocene				Conglomerates and sandy clays	Land and freshwater
	Eocene	Paskapoo	Laramie	Laramie	Laramie	Laramie		
		Edmonton					Sandstones and clays	Freshwater
		Bearpaw	Pierre-Foxhill	Odanah	Foxhill	Foxhill	Sandstones and clays	Land plants, brackish wat
	Montana				Bearpaw	Pierre	Shales	Marine
		Belly R.	Belly R.		Judith R.		Sandstones	Brackish and fresh
		Claggett		Millwood	Claggett	Pierre	Shales	Marine
Cretaceous		Eagle			Eagle		Sandstones	Marine
	Colorado	Niobrara		Niobrara	Niobrara	Niobrara	Calcareous Shales	Marine
		Cardium				Greenhorn		
						Benton	Shales	Marine
		Benton		Benton	Benton	Graneros		
	Dakota	Dakota		Dakota	Dakota	Dakota	Sandstones	Freshwater
	Kootanie					Fuson		
						Minnewaste		
						Dakota	Sandst.&Shale	Land plants
					Cascade			
		Kootanie			Kootanie	Morrison		

Chapter XV.

STRUCTURAL GEOLOGY.

This may be best dealt with by dividing the area into three divisions: (1) Plains; (2) Foothills; and (3) the Rocky Mountains.

(1) Plains region is remarkable for the general horizontality of the strata where the dip seldom exceeds a few feet per mile. Occasionally however the strata is thrown into minor folds with dips ranging up to 30°. Traversing these horizontal beds are three very low anticlines which run parallel to the axis of the Rocky Mountains. These may be called the Bow Island anticline, the Battle River anticline, and the Athabasca anticline. Between the mountains and the Bow Island anticline is a broad syncline. This condition is repeated between the anticlines in going eastward.

(2) In the foothills the strata is much folded and in places faulted.

(3) In the mountains the strata has been broken

into large fault blocks and the whole thrust forward and eastward into the series of ranges we now find the Rockies.

In the north and eastern part of the Province Cretaceous strata rests unconformably upon the Devonian. This unconformity represents a great lapse of time during which Carboniferous, Triassic and Jurassic sediments were deposited over the rest of the Province. The extent of these deposits is not definitely known.

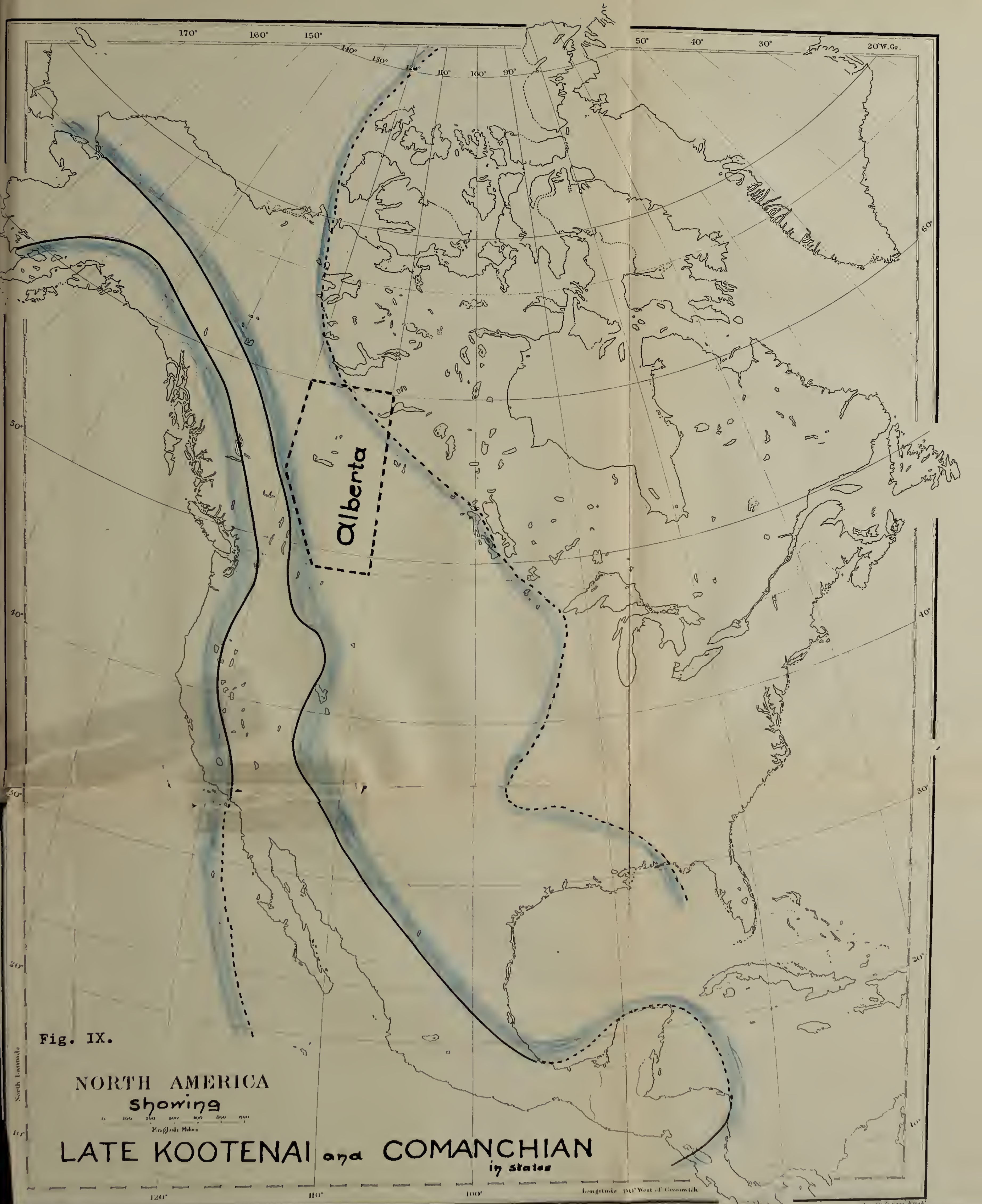


Fig. IX.

NORTH AMERICA
showing
LATE KOOTENAI and COMANCHIAN
in states

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Chapter XVI.

HISTORICAL GEOLOGY.

There is very little data from which to trace the exact history of the geology of Alberta from earliest times to Cretaceous. The outcrops are hundreds of miles apart as from Manitoba to the mountains or Peace River to the Black Hills and Big Horn Mountains. The intervening space is covered and only by the merest conjecture can we fill in what might be below. From the evidence afforded, however, by these widely separated sections, it is probable the floor on which the Cretaceous sediments were deposited was a plane of erosion made up of a series of hardened formations in which the newer were those on the west.

Owing to crustal movements the Cretaceous sediments appear to have been deposited in an irregular manner. The sediments, it would appear, were laid down in a narrow sea along what is now the foothills and Rocky Mountains. Land conditions prevailed throughout portions of the early Cretaceous but it is on the western side of this ancient sea that evidence points to the greatest amount of sedimentation

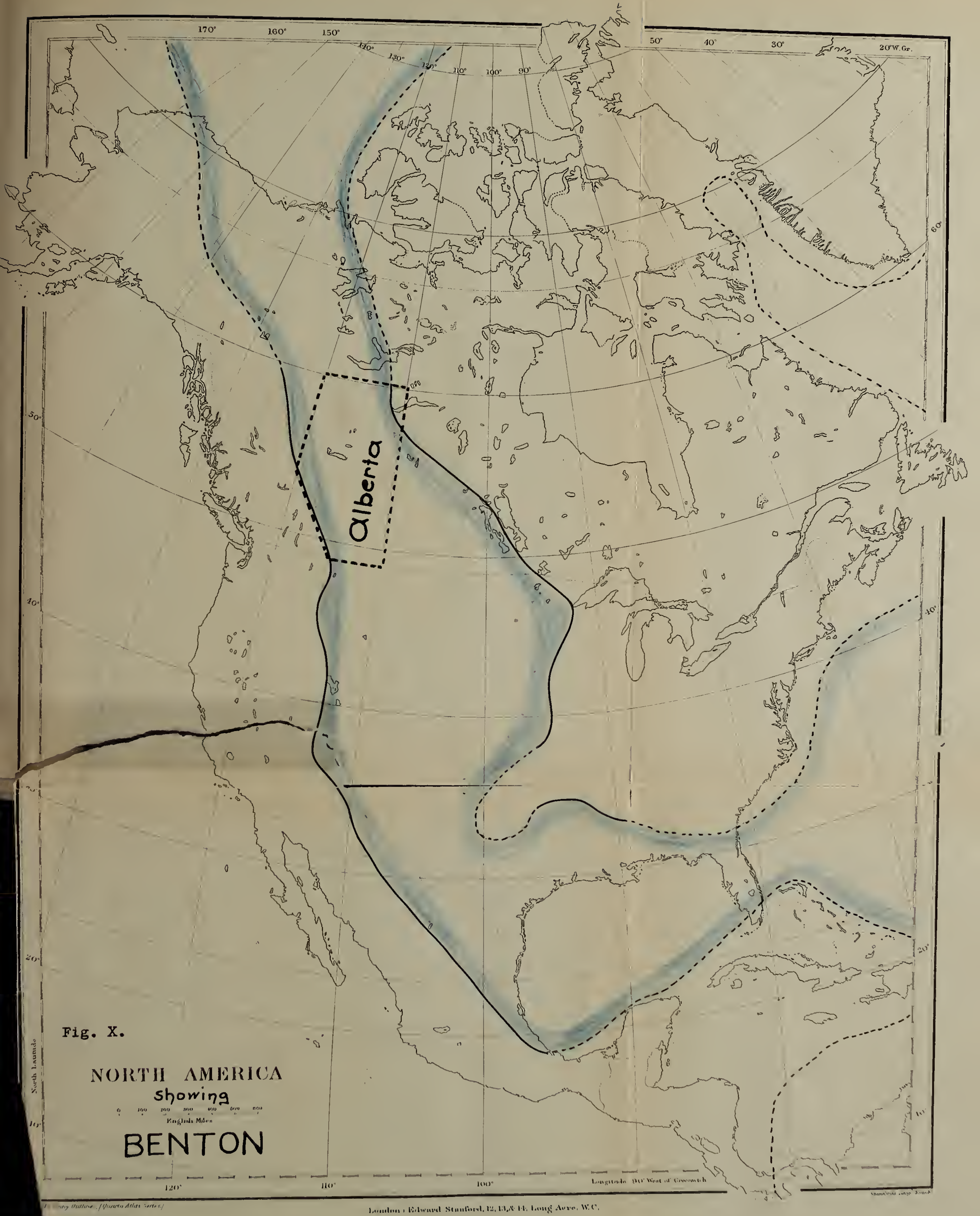

Fig. X.

NORTH AMERICA
Showing
BENTON

Stanford's ... Outline. (Quarto Atlas Series.)

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and an abundance of flora. (see plate opposite).

A general subsidence brought the sea northeastward to cover the Dakota sands with a marine shale. This condition prevailed to the close of the Niobrara. (see plate opposite).

The marine conditions that prevailed during the Niobrara-Benton periods continued for considerable time through Claggett when the oscillations between land and shallow water gave, with each appearance of land, an abundant flora which has been preserved for us in the coal seams of the Belly River. Each coal seam represents a rest in the subsidence of the land area sufficiently long to give remains of a luxuriant vegetation that then flourished and that has been preserved to us as coal.

Again the land sank below sea level for a long period during which the Bearpaw shales were laid down. (see plate opposite). The close of the Cretaceous is marked by an emergence from the sea but the surface remained near the sea level. It is probable that large areas were inland salt lakes which received fresh water from the land drainage. This resulted in time in brackish water the record of which we have in the remains of the animal life. Around these lakes extensive marshes and swamps prevailed

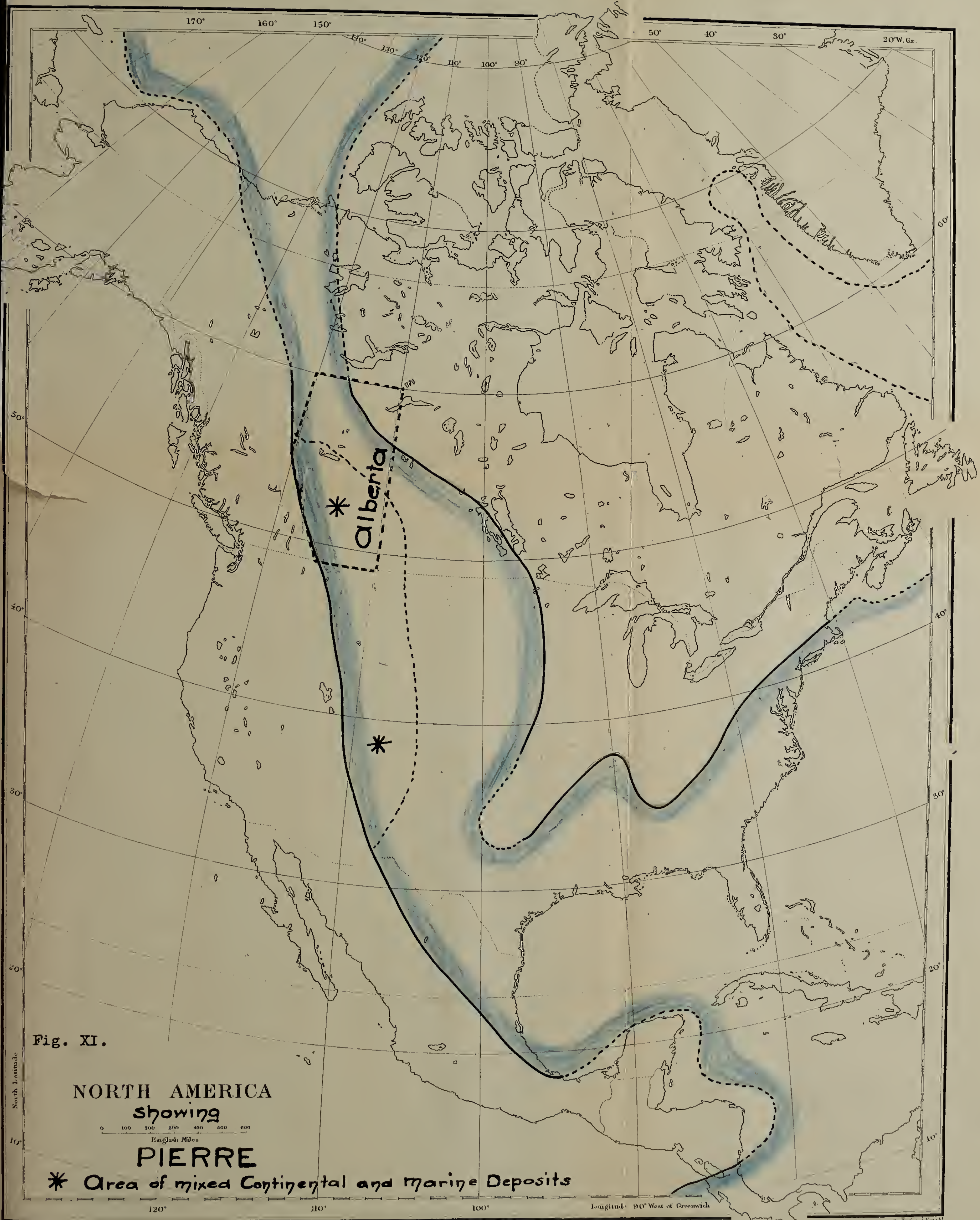

Fig. XI.

NORTH AMERICA
showing
PIERRE

* Area of mixed Continental and Marine Deposits

Stanford's Penny Outlines, (Quarto Atlas Series.)

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Stanford's Geog^l Estab^t

whose record we have preserved for us in the coal beds of the Edmonton series. The close of this period is marked by the uplift of the Rocky Mountains. This was brought about by the transference of great masses of material during the Cretaceous period. This in turn gave rise to crustal movements that forced up the mountains.

From the tops of these erosion has removed great quantities of material that was laid down as Tertiary deposits and which we know as Paskapoo beds.

Chapter XVII.

STRATIGRAPHY.

The formations that lay below the Cretaceous in Alberta have little economic value so far as prospecting has determined and so need not be more than noticed in this paper. The base of the Cretaceous system is of very great importance from the beds of coal it contains and is known as the Kootenai formation.

The Kootenai formation outcrops in the foothills and the Rocky Mountains on the west of Alberta. It is absent in the north on both Peace and Athabasca Rivers. On the east it has not been seen or disclosed in any bore hole. In the states of Dakota and Montana it has been recognized. It would appear that the formation rapidly thins out in going east from the mountains. At Fernie the formation is 5370 thick while eastward at Blairmore it measures only 740 feet. At Bankhead it is 3900 feet and at Moose Mountain to the east it is only 375 feet in thickness. It consists chiefly of dark shales and sandstones. Interbedded with these are the numerous coal seams. One or more conglomerate beds makes a good key formation by which the strata may be traced. This is the most important series as far as

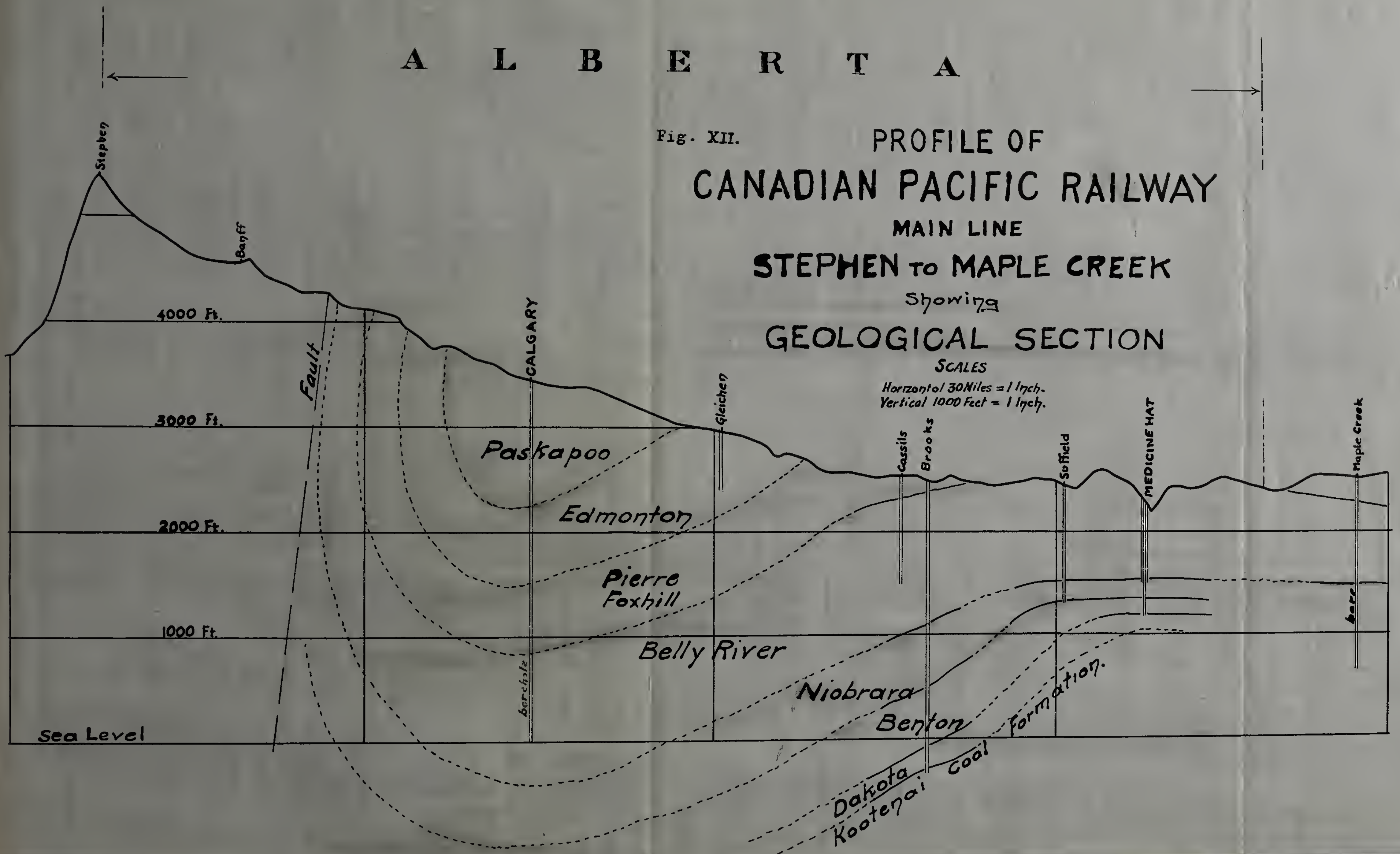


Fig. XII. PROFILE OF CANADIAN PACIFIC RAILWAY MAIN LINE STEPHEN TO MAPLE CREEK Showing GEOLOGICAL SECTION

SCALES
Horizontal 30 Miles = 1 Inch.
Vertical 1000 Feet = 1 Inch.

PROFILE

CANADIAN PACI

MAIN LI

STEPHEN TO MA

GEOLOGICAL

the coal industry is concerned.

The Dakota is the most widely distributed of the Cretaceous rocks. It probably will prove to be of great economic importance in the oil and gas industry. It is the chief reservoir of gas in Southern Alberta and it is the tar sand formation of the Athabasca. For the most part they are sandstone with a few thin coal seams.

Benton is probably of almost equal distribution with the Dakota. It [redacted] consists of dark marine shales overlaying the Dakota sands. It also thins considerably to the east where in Manitoba it is less than 200 feet thick.

Niobrara is of wide distribution in the South of the Province. At Bow Island it is about 500 feet thick. Like the Benton it is a dark marine shale for the most part.

Claggett is the term applied to the portion of the Pierre that lies below the Belly River. It consists of dark marine shales and cannot be separated from Niobrara-Benton except by fossils or where the Cardium sandstone is recognizable.

The Belly River is an important coal formation in Alberta. It consists of light colored sandstones. It passes beneath the Bearpaw to the east and west and is

clearly seen to rest on the Claggett at Pakowki Coulee in southern Alberta.

Bearpaw is that portion of the Pierre which is above the Belly River. It is of wide distribution and extends throughout nearly the whole of Alberta. Essentially it is a clay shale varying in color from gray to nearly black. The fossils show it to be of marine origin.

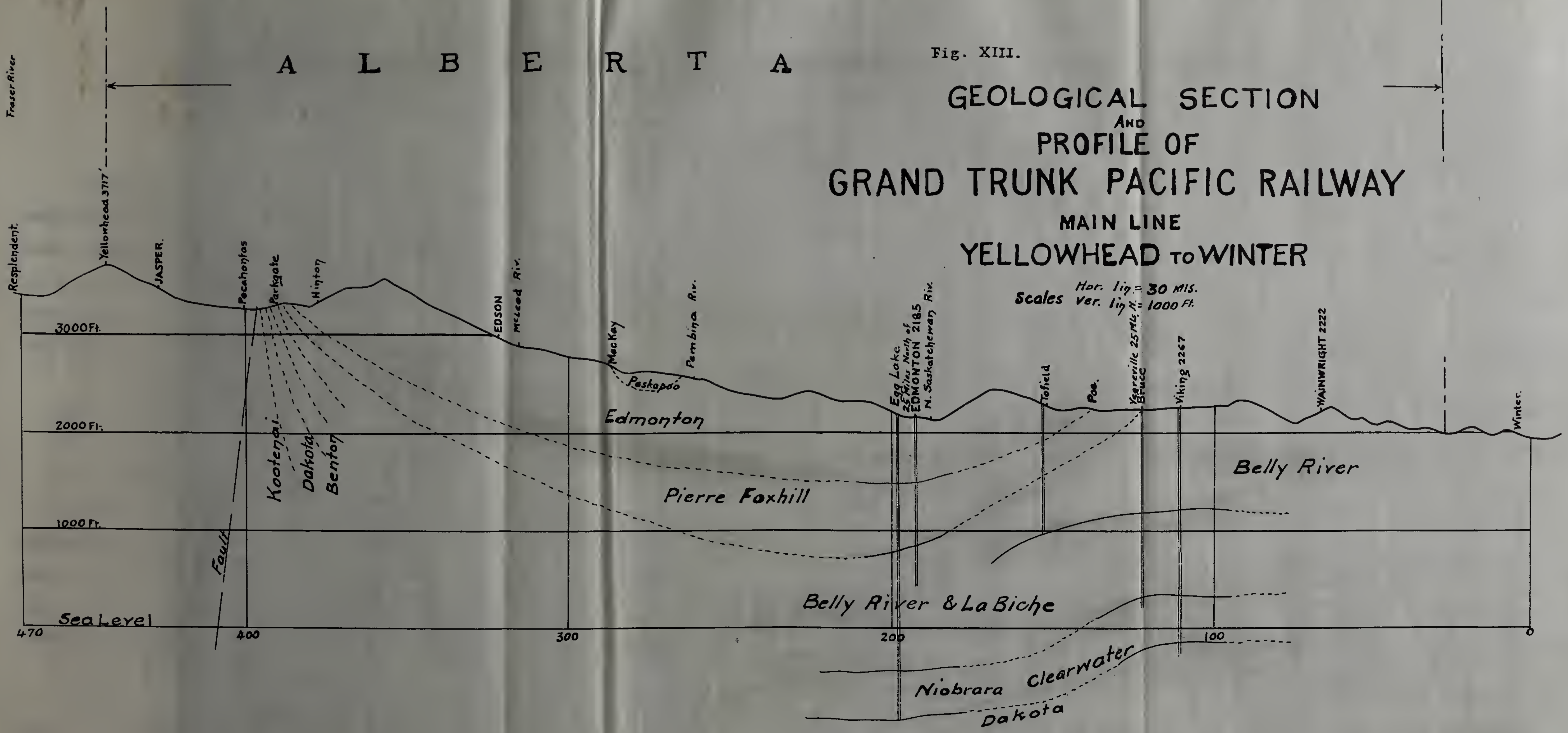
Edmonton series is an important coal formation. It consists of light colored shales and sandstones with seams of coal. It is a brackish water formation. In central Alberta it is 700 feet thick.

Paskapoo overlays the central part of the Edmonton. It consists of yellowish sandstones and olive shales It measures over 5700 feet in its thickest part but much has been removed by erosion from the top.

Oligocene is represented by small area in Hand Hills where the cap is of this age.

Recent or Quaternary consists of the mantle of clay, sands and gravels spread over the surface of Alberta. This is largely derived from glaciation in the mountains.

Fig. XIII.



GEOLOGICAL SECTION AND PROFILE OF GRAND TRUNK PACIFIC RAILWAY

MAIN LINE

YELLOWHEAD TO WINTER

Chapter XVIII.

ECONOMIC GEOLOGY.

Prospecting in Alberta has given indications of many minerals the chief of which are as follows: Gold, iron, salt, gypsum, oil, gas, tar sand, and coal. The coal is by far the most important and we may now consider some of the important areas in which it is found. These may best be considered under the following groups:

I. Kootenai Coals
II. Belly River "
III. Edmonton "
IV. Tertiary "

KOOTENAI COAL AREAS: In the Coal Fields of Manitoba, Saskatchewan and Alberta, by Dowling, is described a number of areas in the Kootenai measures that are of importance. To this list can be added the following that have been the subjects of investigation by the author:

THE SMOKY RIVER AREA.

This area extends up the Smoky River from the mouth of Muskeg River a distance of about 8 miles in cross section. Its extension north and south has not been marked out but it outcrops on Sheep River to

the north and on Sulphur River to the south. These measures are thrown into three arches which run parallel in a northwest and southeast direction. The Smoky River section has five seams each over four feet thick and the thickest seventeen feet.

A large coal area can be looked to be opened up between the Athabasca River and the Smoky. Outcroppings have been discovered on the various rivers between these two. The coal found in the various parts of the area varies in composition from anthracite to bituminous.

Analysis.

No.	Moisture	Ash	Vol. Comb.	Fixed Car.
I	0.9	4.	13.4	81.7
II	2.9	2.2	14.8	80.1
III	1.3	8.	12.5	78.2
IV	0.5	16.5	19.6	63.4

MOOSE CREEK AREA.

This area lies on the above creek just north of the Athabasca River on the Canadian Northern Railway at Brulé Lake. The area is the southern extension of the Smoky River area to the north. It has been examined northward for a distance of about twelve miles and the measures are continuous though thrown into two very sharp folds with down warps to the

strata. There are six coal seams with a total thickness of about forty-six feet of coal. This area lies behind the front range of the Rocky Mountains and in front of the second range. It thus has been subjected to very great stresses and strains which is shown in the physical character of the coal. The coal is very soft and friable, but of high grade bituminous quality. A detailed statement by author may be found in Summary Report G.S.C. for 1911, page 215 and need not be here repeated.

MOUNTAIN PARK AREA.

Lies between the first and second ranges of the Rocky Mountains. It is of great economic importance and is now being actively mined to supply the railway demand for high grade steam coal. It is a southerly extension of the Moose Creek area. The coal measures however have been removed by erosion on the summit between Fiddle Creek and the McLeod River. Except for minor faults the measures are uniform and regular, dipping away to southwest at an angle of about 30°. The measures contain eight seams of workable size with a total coal of about seventy feet. The quality of the coal ranges from bituminous to semi-anthracite.

Analysis.

No.	Fixed Car.	Vol.Comb.	Ash	Sulphur	Moisture
I	61.6	29.1	7.78	.45	.99
II	63.03	27.8	7.1	.39	1.69
III	70.8	22.1	4.3	.56	2.16
IV	52.5	26.8	14.3	.37	6.04
V	55.1	23.6	19.4	.45	1.41

BRAZEAU AREA.

The measures show a continuous extension southward from the Mountain Park to the Brazeau area. Southward the distance between the first and second range increases and so the coal measures occupy a larger area proportionally. Mr. Malloch has examined the strata further south to the Saskatchewan River and they are found to continue. On the Brazeau River and its tributaries a number of seams have been examined where the coal is somewhat soft and friable but of good bituminous quality. The seams range in thickness from 4 feet to 12 feet.

Analytic Statement.

No.	Moisture	Vol.Comb.	Fixed Carb.	Ash
I	.85	17.8	74.2	7.2
II	.89	18.2	74.7	6.2
III	.98	22.	54.6	12.3
IV	2.4	23.6	67.4	6.6

The southward extension of these measures are described in G.S.C. by Malloch in his report on Big Horn Coal Area. Further south they are described by Dowling in Coalfields of Manitoba, Saskatchewan and Alberta.

It is thus seen there is no outcrop of the Kootenai measures east of the mountains. This is due to the Geological structure of the country. In the uplift of the Rocky Mountains the deeply buried Kootenai was up-turned and brought to the surface thus exposing the coal seams.

BELLY RIVER AREAS.

Coal is not mined in this series outside of southern Alberta. Around Lethbridge the mines are all in this series and a good grade of domestic coal is put on the market. This coal horizon is above the Kootenai and separated from it by a very thick series of marine shales. At Diamond City near Lethbridge the measures were examined where the Diamond mine is opened up on a seam 8 feet thick. The seam gives the following analysis: Moisture 4.4; Volatile 34.6;
Fixed Car.50.4; Ash 9.9

EDMONTON COAL FORMATION.

The fertile portion of the Edmonton formation forms a ring around the Paskapoo series of rocks and is

found dipping under it. On page 40 of Coalfields of Manitoba, Saskatchewan and Alberta is found a description of a number of localities of Edmonton coal. Other notable places are the Pacific Pass Mines, the Yellowhead Mines, Morinville, and at points along the Calgary branches of the Grand Trunk and Canadian Northern Railway.

At Tofield two mines are working on 8 foot seam by stripping the overburden with steam shovel and quarrying the coal. At Drumheller a good quality of coal is mined from 8 foot seam that finds a ready market in Saskatchewan.

THE TERTIARY COAL is not mined in Alberta.

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